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Two European Direct-Current, High-Tension Transmissions.

BY FRANK C. PERKINS.

EUROPEAN engineers, most notable among whom is M. Thury, of Geneva, have developed the use of direct currents for high tension transmission purposes along lines that are quite unknown in American practice, and their methods of direct-current transmission cannot be without interest in this country where alternating currents hold exclusive sway in all transmission work involving great distance or high voltage.

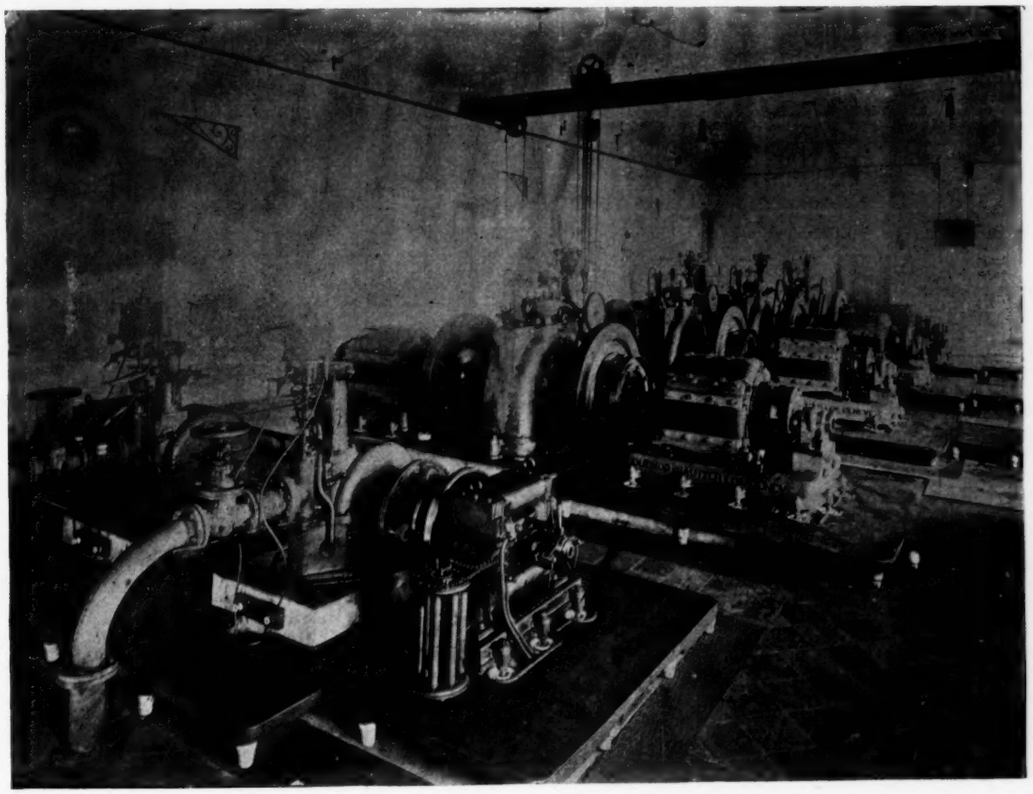

FIGURE 1.—"VOLTA" POWER HOUSE OF THE ISOVERDA-GENOA DIRECT-CURRENT TRANSMISSION.

On this page (figure 1) is given an illustration of the interior of a power station generating direct current for a transmission of this character. The power station is known as "Volta" and it is one of the three similar generating plants for the transmission from the mountains at Isoverda to Genoa, Italy. The interior of another of the power houses of the same system and which is known as "Paccinoti," is shown in figure 2. The potential used in the Isoverda-Genoa Transmission varies from 8000 volts to 13,000 volts and a constant current of about 65 amperes is maintained, the voltage, of course, being variable with the load. The fields of the machines shown in figure 1 are excited by the direct-connected dynamos seen in the foreground. The valve of the exciter turbine is operated by a solenoid as shown, and link couplings are used between the wheels and dynamo shaft. It will be noted that the bases of the generators are doubly insulated by porcelains. The voltage of each machine varies from 1000 volts to 1200 and the regulation is said to be within two per cent.

The method of insulation used may be more readily understood from the illustration (figure 3), of a direct

current motor built by the Compagnie de l'Industrie Electrique, of Geneva, for high tension service, and which was shown at the Paris Exposition. The normal speed of this motor is 400 revolutions per minute, delivering 100 horsepower. It is designed for use on a direct current line having a maximum potential of 20,000 volts. The Isoverda-Genoa direct current transmission was projected by M. Thury, engineer of the company just named, and it is of historical interest to note that this "Thury" system is the one originally receiving the highest prize by the Niagara Power Commission in 1890, while the Niagara Power Company was investigating the various systems for use in the then-proposed Niagara-Buffalo transmission. The great success of the multiphase system as first introduced, at the Frankfort Exposition in 1891, however, turned the tide of sentiment in favor of that system and it was finally decided upon for use at Niagara.

Another interesting direct current power transmission is that which has been installed at Chaux-de-Fards and Locle, which is also of the "Thury" system. The hydraulic construction of this plant consists of the dams and reservoir in the mountain and the canal which conveys the waters along the side of the embankment to the power house. The fall is 91 meters and the aqueduct has a capacity of 5 cubic metres of water per second the normal flow is below this amount, being estimated at 3000 litres. The capacity at low water was less than 1700 litres per second.

The Districts of Chaux-de-Fards and Socle have a right to 70 per cent of the available water while the city of Neuchatel owns the balance of the supply. Two power flumes 1.100 in diameter are used, each having a length of 200 metres and terminating at the power house supplying the distribution for Chaux-de-Fards and Locle. The dynamo room has space for nine groups of generators; four are at present in operation, while a fifth is held in reserve. The available power at mean water permits the operation of eight groups of generators. The direct current generators are connected in series and deliver a constant current of 150

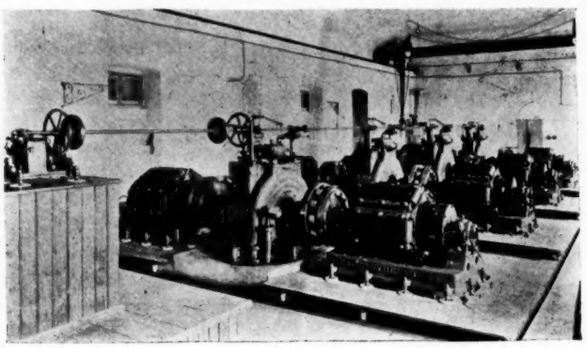

FIGURE 2.—POWER HOUSE "PACINNOTI."

amperes under a tension of 14,400 volts and have a capacity for 3600 horsepower.

The turbines and generators are very similar to those shown. The generators are of the design of M. Thury and were also built by the Compagnie de l'Industrie Electrique of Geneva, Switzerland. The dynamos are of the six-pole type and the armatures are 1250 milli-

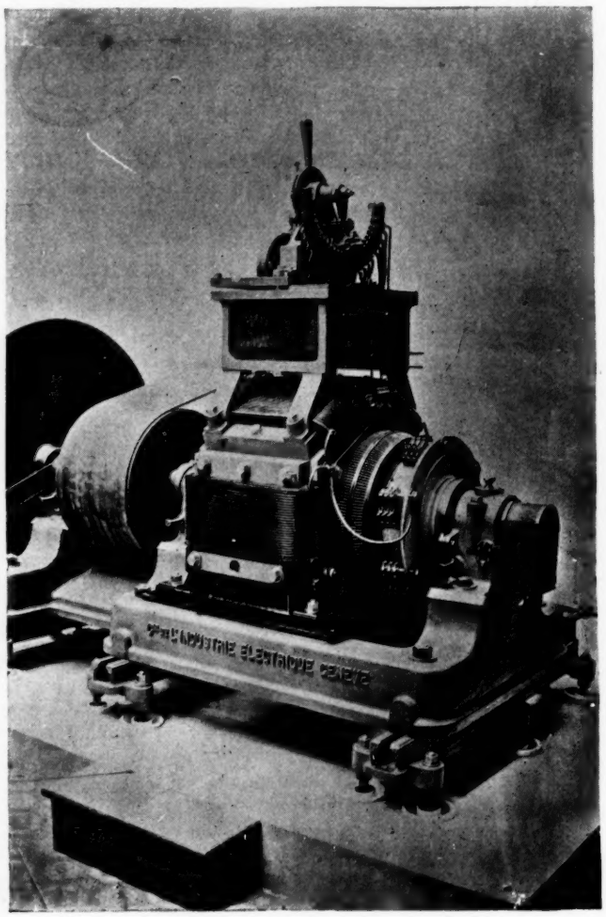

FIGURE 3.—THE THURY MODE OF INSULATING A MOTOR ON A 20,000-VOLT D. C. TRANSMISSION.

metres in diameter. The winding is of the drum type, while the field excitation of the various machines is in series. The generators operate at a speed of 300 revolutions per minute and give a maximum voltage each of 1800 volts, although they have each been tested to 2700 volts.

The high tension line carries direct current at 14,400 volts. The cables have a cross-section of 150 millimetres and are 52 kilometres long. The transformer stations contain direct-connected motor-generators. The motors and lights represent about 2000 horse power and the tension of the secondary generators is 150 and 300 volts. The transformation for the street railway power plant is by means of motor-generators delivering a 500-volt direct current.

At one of the transformer stations seven of the motors representing 400 horse power, supply power for commercial use in the distribution.

Engineers who do not patronize THE JOURNAL are aptly defined by the vernacular as "dead ones." Reader, are you alive?

Operation

PERIODICITY IN A. C. APPARATUS.*

BY JAMES M. ANDREWS.

IN cases where the alternating system of distribution is applicable or desirable, the choice of frequency or periodicity becomes a matter of great importance, and this can only be decided after all the conditions of the problem are thoroughly understood. In this country we are fortunate in having but few standard periodicities, but abroad there seems to be no recognized standard, every conceivable frequency being used.

All alternating-current apparatus, whether single or polyphase, can be classed under the two heads of high or low frequency, but it is with low-frequency machinery we have most to do. All periodicities of 100 or more cycles per second are termed high; all below that, low. The only standard high frequency that we shall touch upon is 125 cycles, although in certain old plants the periodicity is much higher. The lowest frequency to be referred to will be 25 cycles, though there are plants today operating at a much lower periodicity. An instance of this is a railway system in Italy, which is built for 15 cycles. This road is about 60 miles long and the current is supplied to the car at a potential of 3,000 volts.

In order to present this matter as clearly as possible, and to cover all probable conditions which may arise, I shall take each periodicity separately and discuss its value as regards transformers, line losses, induction motors, synchronous motors, rotary converters, incandescent lamps, arc lamps, parallel operation and the different systems.

125 Cycles.

The principal field for systems operating at this frequency is in small distributions of scattered load, and where individual customers or groups of customers are supplied over their own primary lines, or, in other words, where the secondary networks, if any at all, are of relatively small importance. This frequency is used almost entirely for lighting alone, although a small percentage of motor load can be carried without trouble. The generators operating at this frequency are usually of small capacity, rarely exceeding 200 kilowatts, and, due to their necessarily high speed, they are usually of the belt-driven type or directly connected to high-speed waterwheels.

Transformers.—It may be stated, as a general rule, that the higher the frequency the smaller can a transformer be made, or, in other words, for transformers of the same size, a high-frequency transformer can be made with better efficiency than a low-frequency one.

Line Losses.—As stated before, the principal field of the 125-cycle system lies chiefly in distributions where the load is scattered and where there is but little or no secondary distribution. This being the case, the effect of the relatively large reactance in 125-cycle wiring is not very objectionable, and, in fact, it can often be disregarded, whereas, in an extensive secondary network, using large conductors, a considerable increase in line drop takes place, and therefore, for a given loss, the amount of copper has to be increased. For example, No. 0 wire has 0.114 ohm reactance per thousand feet at 60 cycles, and 0.24 ohm at 125 cycles, with a resistance of but 0.1 ohm, showing that reactance is more than twice as large as the resistance, and, therefore, the effect decidedly noticeable. These figures on the reactance are based on the assumption that the wires are placed 18 inches apart. Such a size of wire, however, would probably never be used in a primary line, but something smaller, say, No. 4 B. & S., which has about the same reactance as resistance. With the larger wire and cross-section of copper, the drop in voltage in the line is 45 per cent. greater in the 125-cycle installation than the 60-cycle installation, practically independent of the power factor of the load, whereas, with the smaller wire, it is but 20 per cent, more, depending upon the power factor.

To compensate for the increased amount of copper necessary for the same drop in voltage, it is to be remembered that the size of transformers, motors and condensers, and, in general, the load on the system, is smaller than at the lower frequency, so that it will sometimes be found commercially advantageous to use the higher frequency, notwithstanding the increased line drop and expense in line copper.

Induction Motors.—Induction motors operated on high-frequency circuits usually run at higher speeds than those of lower frequency. This is more marked with single-phase induction motors, which type is undoubtedly the most commonly used for 125-cycle installations. The constants of these high-frequency single-phase motors are very good, if built of the definite or polar-wound armature type and used in connection with condensers. These motors can also be built of the squirrel-cage type and started with, say, one-third full-load torque, even with a comparatively moderate amount of current and condenser capacity. By using the most favorable portion of condensers, the power factor of these motors is as high, or, indeed, higher, than that obtained in any other type of motors, approaching 100 per cent. at almost all loads. The efficiency, however, is necessarily somewhat lower, with the result that the apparent efficiency, or the ratio of the watts output to the volt-ampere input is the same, or lower than with the corresponding three-phase type of motor. In general, it may be stated that, due to the necessary complications, such as condensers and compensators and the attendant chances for trouble, single-phase motors are not to be recommended or used where the polyphase type of motor can be employed.

Synchronous Motors.—This type of motor is more satisfactory when supplied with power from turbine-driven or belt-driven generators. As a rule, it is not advisable to install any high-frequency synchronous motors, as there is a tendency to "hunt," and since high-frequency systems are primarily lighting systems, any motors which take or tend to take a pulsating current under certain conditions of load must be very objectionable.

Rotary Converters.—The above discussion applies also to rotary converters, but it should be stated, in addition, that it is very difficult to build a converter to be used on circuits of this frequency, on account of the necessarily high commutator speed and the short neutral incident to the great number of poles. Small units can, however, be made, but they can hardly be considered commercial at the present time.

Arc Lamps.—The power factor of arc lamps decreases as the periodicity increases, but the change is so slight as to be negligible and the lamps are perfectly satisfactory at this frequency.

Incandescent Lamps.—Incandescent lamps have been used for so many years on high-frequency systems that there is no necessity of stating that their operation is perfectly satisfactory. The higher the frequency, the more uniform is the light obtained, and the pulsating brilliancy, which is noticeable on some low-frequency circuits, cannot be detected on 125-cycle circuits.

Parallel Operation.—In the case of generators operating from independent engines and running from belts, or directly connected to high-speed turbines, it may be stated that they will operate very satisfactorily in multiple, but at present at seems improbable to obtain reciprocating steam engines which will regulate closely enough to insure satisfactory parallel operation of direct-connected, slow-speed, high-frequency alternators.

Systems.—Due to the reasons given above, this frequency is almost entirely chosen in single-phase distributions, although two-phase, three-phase and monocyclic systems of periodicity have been brought into commercial use.

In general, it may be stated that the only reason why plants of this frequency should be purchased is the fact that, originally, only 125-cycle apparatus was manufactured, and as it will not always pay to throw out a plant already installed, the additions and enlargements will be of the same frequency.

*Abstract of a paper read before the Ohio Electric Light Association at Toledo, August 15, 1900.

60 Cycles.

This frequency is particularly suited for power transmission where the chief load is lighting, and the lighting is in defined and dense districts, so that the secondary distribution can be conveniently and commercially installed in such a manner that the cost of the relatively few large-size transformers will not amount to more per kilowatt than the cost of a great many high-frequency transformers in a system with scattered load. This system is also very suitable for induction-motor work and fairly good for synchronous motors and rotary converters.

Transformers.—What has already been said with reference to 125-cycle transformers applies also to those for this periodicity; that is to say, that for the same losses, the transformers are somewhat larger for this frequency.

Line Losses.—In smaller wires the line drop is about 15 per cent. greater than the "CR" loss, but with larger wires,such as No. 00, assuming 18 inches between them, the drop would be about 40 per cent. greater, depending upon the power factor. This shows that in laying out the secondary network every effort should be made to use the smallest wires possible, and that when large wires are necessary, they should be placed as close together as can safely be done, when the effect of reactance becomes negligible.

Induction Motors.—These are usually of the multiphase type and should, therefore, be compared with other low-frequency motors. As built today, the speeds of 60-cycle motors are approximately the same as those for 40 cycles, even in the smaller sizes, but the power factor, however, is somewhat lower. The maximum output of the 60-cycle motor is approximately 15 per cent less than with 40-cycle motors, although large enough, averaging more than double-rated output.

Synchronous Motors.—On circuits of very uniform frequency, and particularly in systems using turbine-driven or belted generators, 60-cycle synchronous motors, as a rule, operate very satisfactorily. Considering, however, that any sudden fluctuation in load is liable to cause a large flow of current and somewhat unstable operation, particularly when the synchronous motor is fed over a line of high resistance, they are not so well suited on most 60-cycle systems which have considerable lighting load.

Rotary Converters.—Although a great many 60-cycle rotaries have been installed during the last few years, it seems to be conceded that they are not as successful as those of lower frequencies. Their commutator speed is high, the width of segments a minimum, and the distance between brushes short, all of which features are undesirable. If they are to operate on lighting systems where any pulsation in current caused by even a slight hunting is objectionable, it is readily seen that they cannot be recommended, except in cases where all the conditions are extremely favorable.

Incandescent Lamps.—Incandescent lighting, as far as light is concerned, is undoubtedly satisfactory, and the most scrutinizing investigation can hardly detect any difference between 60-cycle and 125-cycle lamps.

Arc Lamps.—Due to the higher power factor of 60-cycle lamps, they are preferable to 125-cycle. Theoretically, however, as stated before, the difference is immaterial.

Parallel Operation.—All turbine or belt-driven generators operate in parallel without any difficulty. With direct-connected, slow-speed units, however, difficulties will arise, provided the engines are not built with the very closest speed control and favorable governing mechanism.

Systems.—All systems are now used with this frequency. Indeed, this is the only standard frequency which is used as often for single-phase as for two or three-phase installations.

40 Cycles.

In very many places, and particularly in industrial districts, the greater percentage of power is used for motors, yet lighting is desired and must be accomplished with the least amount of complication. Under such conditions 40-cycle systems are preferable to all others.

Transformers.—Assuming the same electrical constants, 40-cycle transformers of moderate capacity are somewhat larger than 60-cycle transformers and smaller than 25-cycle transformers.

Line Losses.—With average size of wires and the usual distance between them, the drop is but five or 10 per cent. higher than the ohmic loss, but with the larger sizes, for instance, No. 00 B. & S. gage, it amounts to as high as 25 to 30 per cent. more than the ohmic loss under the same conditions. In this connection, however, it must be remembered that self-induction is often not only not objectionable, but advantageous. This is the case in rotary converter and synchronous-motor installations where potential control is desired.

Induction Motors.—As may be already anticipated from the discussion of induction motors for 60 cycles, we would judge that the 40-cycle motors should be somewhat heavier than 60-cycle motors, with the advantage of one or two per cent. higher power factor at full load. The maximum output is about 2½ times the rated output.

Synchronous Motors.—Although synchronous motors for 40 cycles are not quite as stable as those built for the lower frequency, 25-cycle system, no difficulty should be anticipated, particularly if the generators are turbine or belt-driven, and even with power supplied from direct-connected, slow-speed engines, very little, if any, difficulty whatever need be expected. This is the more so when several induction motors are installed on the same system, when the effect of the lagging current caused by induction motors neutralizes the leading current caused by the synchronous motor.

Rotary Converters.— Converters of this frequency combine the advantages of the 25-cycle machines without the disadvantages of the 60-cycle rotaries. In other words, they are rated at a moderate speed, can be operated on circuit having considerable losses, but need somewhat more attention than slow-speed, direct-current machines, but much less than higher-frequency rotaries. On circuits of high losses, and, in general, on circuits where the power of the generating apparatus is not large, compared with the power of the rotary converters, the lower frequency is preferable.

Incandescent Lamps.—Incandescent lighting, at least on circuits of moderate voltage, requiring lamps with large filaments, is quite satisfactory with 40 cycles. With very high-voltage lamps, however, some flickering may possibly be noticeable, particulary with a fast-moving object in front of the light. For all general work, however, this is not objectionable, and it is only when we get as high as 220 volts that any trouble will be experienced.

Arc Lamps.—Arc lamps, as at present designed, are satisfactory on 40 cycles for outside work, but for interior lighting, it is a matter of personal opinion. Below this frequency, however, the lamps cannot be considered as meeting all requirements, as there is annoyance caused by the flickering, with an object moving at a very moderate speed in front of the lamp.

Parallel Operation.—If care is taken to secure close speed-regulating engines, no difficulties need be anticipated in parallel operation of slow-speed, directly connected units, and this being the case, it is self-evident that belted or turbine-driven generators can be run in multiple without the slightest trouble.

25 Cycles.

Twenty-five-cycle systems are largely recommended in distributions where practically the entire load consists of a power or direct-current load through rotary converters, with the possible exception of a very small alternating-current load, in which case motor-generators or frequency changers are used. Due to the low frequency, even moderately good engines will permit of operating directly connected generators in multiple, and synchronous motors and rotary converters will run satisfactorily without hunting.

Transformers.—Twenty-five-cycle transformers are seldom used in small sizes, but mostly in large units and of the air-blast

type. Transformers for this frequency are, for the same electrical constants, about 15 per cent. heavier than for 40 cycles.

Induction Motors.—Twenty-five-cycle induction motors are necessarily heavier than those built for 40 or 60 cycles, and have a very high power factor, reaching 94 to 95 per cent. in fair-sized units.

Synchronous Motors.—Twenty-five-cycle synchronous motors have been used and are used to a great extent, and they are perfectly feasible on almost any system. It is, however, always advisable to investigate the generating station before determining to use synchronous motors, for the reason that if the synchronous motor is large, compared with the power of the station, it may be found difficult to maintain constant voltage, due to some slight hunting, which might occur. From belt or turbine-driven generators no trouble should occur, provided the losses between the station and synchronous motor are not too excessive.

Rotary Converters.—This frequency is naturally best adapted for rotary converters, and the converters themselves are built with essentially the same mechanical constants as direct-current generators. The peripheral speed of armature and commutator is as low as is used in many of our direct-current machines, and they require, if anything, less attention than they. One of the greatest advantages, from the operating point of view, of the 25-cycle rotary, compared with the rotaries designed for higher frequency, is that very little care, if any, need be taken in synchronizing. As a rule, the rotaries might be driven up to a fair speed and then their fields opened and the alternating current thrown on and no disturbance on the commutator will take place, and the effect on other rotaries operated on the same system is not serious. Twenty-five-cycle rotaries, being decidedly stable machines, permit of being operated with phase control; that is to say, they can be built with considerable series field and used in connection with reactive coils for maintaining constant potential, or even increase their voltage with the load. This latter feature is rarely possible with 40 or 60-cycle converters.

Incandescent Lamps.—Twenty-five-cycle incandescent lighting can hardly be considered a commercial success, except for street lighting at low voltages with poor economy. Flickering can be noticed even with 52-volt lamps, and this is, of course, more pronounced in lamps of higher voltage.

Arc Lamps.—Arc lighting at this periodicity is out of the question, and there is but little possibility of its ever being accomplished satisfactorily.

Parallel Operation.—Parallel operation of 25-cycle generators, even when running at low speeds and directly connected to engines, has rarely ever involved any difficulty if the engines have reasonably close regulation. In fact, almost any engine seems to be good enough for the purpose, although we naturally prefer to get engines of fair regulation as to rate of rotation per revolution.

Systems.—Twenty-five-cycle installations are usually three-phase, and, of course, always of one of the multiphase systems. It is advantageous to build rotary converters with six-phase connections, but six-phase power can, of course, be supplied directly from two or three-phase systems, by means of transformers.

Summary.

It will be seen from the foregoing that a great deal of thought must be given to the work required for a given installation before the proper periodicity can be settled upon, but, in a general way, it may be stated that, for small plants doing lighting alone, with scattered load, high frequency and single phase would be selected; for general lighting, with a moderate amount of power, 60-cycles, multiphase, and for general power, with a moderate amount of lighting, 40 cycles, and for the power alone, using rotary converters, 25 cycles. Of all the frequencies mentioned, the one which seems to be the most universal in its application, where power is required, is 40 cycles.

Traction

A 3000-VOLT THREE-PHASE RAILWAY.*

BY E. K. SCOTT.

FROM an electrical novelty point of view, probably the most interesting exhibition at the Paris Exhibition will be the plans, details of electric cars, etc., for the 65 miles of electric railway which the Adriatic Railway Company is building at Colico, Italy, the trolleys for which are at a pressure of 3000 volts. The objects to be exhibited include details of the line equipment, models of a transformer sub-station and a parlor motor carriage of 300 horsepower, besides switches and other details. These will be exhibited in a pavilion which is being specially built by the Adriatic Railway Company, and which will be ready by the end of July. The line itself will not be ready for use before 1901, but some six months ago Messrs. Ganz & Co. erected an experimental line about one mile long at Buda-Pesth on which all the details are being carefully worked out.

The lines being converted are those of Lecco-Colico, Colico-Sondrio and Colico-Chiavenna, which are at present worked by steam. The necessary power will be derived from a 98-foot fall on the River Adda; the head race is three miles long, and at the power station at Morbegno (10 miles from Colico) 10,000 horsepower will be available. It is proposed to erect three units of 2000 horsepower each, consisting of turbines and Ganz three-phase alternators, generating current at a pressure of 20,000 volts and 15 periods per second.

At intervals of about 6½ miles there will be 10 transforming stations, reducing the pressure to 3000 volts on the trolley wires, which are 315 mils in diameter. Both the primary and secondary lines are on the same poles, except in the tunnels where the lines are fixed to the roof. The two overhead wires are three feet apart and the rails form the third conductor. The passenger cars are to have four motors, each 150 horsepower. Two motors only will be in circuit at the maximum speed of 38 miles per hour, the other two being thrown into circuit when the train of 65 tons weight ascends gradients of above 1 in 100 at 19 miles per hour. When the four motors are in use two of them take current, not from the trolleys, but from the other two motors—that is, the motors are connected in tandem or in concatenation; in this way it is said that the speed is reduced to one-half without serious loss of energy. There are to be five passenger trains and two freight trains, the freight trains being run at about half the above speeds and having a maximum capacity of 200 tons; they are run by a 600 horsepower locomotive.

The whole of the line is divided into single parts, each of which is supplied with current from the sub-station next beyond it, this being done to insure greater safety in working. When one block signal indicates "stop," the next part of the line is not supplied with current, and in case of interruption of current the Westinghouse brake comes on automatically, an important feature on a line with steep grades.

This line is of international importance, because the Adriatic Railway Company is one of the two largest railway concerns in Italy, controlling as it does the whole of the railway network down the eastern portion of the kingdom.

The decision to undertake the work is the direct result of the successful operation of a short length of electric railway from Milan to Monza, and it is further interesting to note that the company is so pleased with the way that things are shaping that it already contemplates equipping electrically the Bolgna-Firenze line, which is several hundred miles long and crosses the highest point of the Appenine range of mountains.

The Mediterranean Company, which controls the railway system on the west of Italy, is following suit, and has already obtained the royal decree to a project which will require 10,500 horsepower. Electrical engineers, and also railway engineers, will therefore need to watch these Italian developments closely, for, as was the case with the Tivoli-Rome transmission†, it is again falling to Italy to lead the engineering world.

**The Electrical Engineer*, London, Vol. XLVI, page 960, June 8, 1900.

†For detailed description see *Cassier's Magazine*, Vol. XV, page 331, March, 1899.—THE EDITOR.

The Pacific Coast Gas Association.

Papers Read Before Its Eighth Annual Meeting, Held at the Offices of the San Francisco Ga and Electric Company, in San Francisco, July 10, 11 and 12, 1900.

THE SYNTHESIS OF COMMERCIAL GASES.

BY LEON P. LOWE.

THE writer desires to preface his remarks by stating that it is his intention to deal with this subject in a very simple and elementary way, refraining, as much as possible, from the use of technical terms, chemical formulæ and symbols, feeling, as he does, that it will thus be more comprehensive to those who are in search of a better knowledge of that mysterious and invisible substance commonly known to the civilized world as "gas;" for it may be safely said that, upon the mere mention of the subject, the mind of the average hearer at once reverts to the article which he recognizes as being in common daily use for the purpose of giving light and heat.

In his business it has been the fortune of the writer to visit many gas works, wherein he has met a host of those solid, hard-working, good fellows who largely make up the gas fraternity; and during these visits he has, in his talks with many of those connected with the works, been struck time and again with the necessity of a very elementary, simple and practical description of the composition of commercial gases, and from time to time has promised himself the pleasure of undertaking the slight task which he now hopes may prove of assistance to those members of the gas profession who, after having secured a practical knowledge of gas, desire to familiarize themselves with its chemical properties without being compelled to take up a line of study to which they cannot devote enough time for its mastery in the usual way.

The writer thoroughly believes in the policy of a liberal education, even to the extent of teaching gas consumers what may seem to them the intricacies of the gas business, for nothing tends to make a person more satisfied with any article he is using than a knowledge of its nature and composition. It would, therefore, seem a wise and good business policy for every one connected with the manufacture and sale of gas to have a comprehensive and explainable understanding in a simple way of the nature of all gases in general commercial use, as they will find it very useful in many ways, and a stepping-stone to a broader and deeper study of one of the most important business industries of all civilized countries.

The term "synthesis" has been chosen as meaning the opposite of analysis, the latter being the act of the taking apart or breaking down of a substance, while the former is to assemble or build it up.

It is simple enough for the gas analyst to collect a sample of gas and by the various processes at his command to, step by step, analyze or take it apart, which may furnish him with the information sought, but if his labors are performed in the presence of others unskilled in his art, he is able to show but little of what he is accomplishing, taking, as he does, a sample of an invisible substance from which he extracts numerous other invisible substances, finally completing his labors with an announcement of the chemical composition of the gas sample upon which he has been at work, while his observers can do but little else than look wise, accept his statements and keep silent.

Ordinary illuminating or heating gases in a finished, purified state are in one sense very simple, and in another sense very complex bodies, for while but four of the elementary substances, viz., carbon, oxygen, hydrogen and nitrogen, enter into the composition of such gases, some of them are combined in almost innumerable forms.

Three of these substances, oxygen, hydrogen and nitrogen, are contained in their natural or free state, while the fourth, carbon, is always found combined with either oxygen or hydrogen. When combined with oxgen it is either in the form of what is known as carbonic acid or carbonic oxide, and when combined with hydrogen is in the form of what is known as marsh gas, or a series of combinations of carbon and hydrogen, which go to make that part of lighting gas commonly known as the "illuminants."

It may simplify matters to briefly explain the difference between chemical substances in their natural or free state and when combined with other bodies, and for this purpose a familiar illustration of a household nature will be used.

Take, for instance, the articles which go to comprise bread, choosing them in their proper proportions, after which, by mixing and baking them in the usual manner, there will result the familiar loaf of bread, an article which, while containing many substances, in no wise resembles its original component parts, and which cannot be mechanically separated and put back into them. These parts may be said to be the elements of the bread, and that article the resulting combination of its parts.

Now, from the same substances which went to make the bread, we can, by altering their proportions, make other kinds of bread, and also crackers, cake, etc., which, while composed of the same materials as the first bread, are recognized as distinctive substances in themselves.

If, for example, we make up batches of several kinds of these articles and cast the whole lot into a suitable receptacle, we can, by proper mixing, prepare a mass all portions of which will average about alike, but which, if we attempt to take it apart minutely, will be found to consist of our bread, cake, crackers, etc.

Bearing this simile in mind, we may now proceed with the consideration of what happens during the process of gas-making, and which generally applies to all gas processes alike.

The apparatus being in a working condition, that is to say, in the practical methods of the day, being properly heated, the gas-making materials are introduced therein and the evolution of the gas takes place. The materials used are composed of but the four elementary substances above referred to, viz., carbon, oxygen, hydrogen and nitrogen, in either a free or combined state; hence it is that the ultimate composition of the gas is limited to these four substances, which, however, under the action of heat can and do associate themselves into numerous compounds, as in the case of our bread illustration, and which, after they are once formed, are capable of being taken apart only in their new forms.

In gas-making the elementary substances, carbon, oxygen and hydrogen, combine with one another as follows: carbon with oxygen and carbon with hydrogen.

The carbon and oxygen can combine in only two proportions, there being but two compounds of those elements known to chemistry, one of which is commonly called carbonic acid and the other carbonic oxide.

Carbon and hydrogen can and do combine with one another in such an infinite number of forms that, in ordinary commercial gas practice, but two such compounds are usually recognized, one of them being known as marsh gas, while all of the others are grouped under one head and commonly called "illuminants." These illuminants, however, in average compositions, closely resemble another compound of carbon and hydrogen known as ethylene, and for practical purposes they are frequently considered as being that gas. In addition to the above combinations,

oxygen, hydrogen and nitrogen are found in their free and uncombined state.

Starting with four elementary bodies, we have now multiplied them to seven, as follows: 1st, carbon and oxygen to form carbonic acid; 2d, carbon and oxygen to form carbonic oxide; 3d, carbon and hydrogen to form illuminants; 4th, carbon and hydrogen to form marsh gas; 5th, hydrogen in its free state; 6th, oxygen in its free state; 7th, nitrogen in its free state.

In the usual, practical gas analysis of the present day these seven substances comprise the list of the gaseous bodies usually recognized as comprising all commercial gases, their proportions only being varied to make the different kinds of coal, water and producer gases in general use.

From the above it will be seen that, while our original elements have associated themselves to form various compounds, these compounds once in the finished gas retain their individuality and can always be separated as such, showing our completed gaseous body to be merely a mechanical mixture of various chemical substances.

Having thus followed the building up or synthesis of our gas to its ultimate composition, we will now more minutely examine its component parts with reference to both their physical and chemical properties. The determination of the above seven gases in an ordinary gas analysis is in the following order: Carbonic acid, illuminants, oxygen, carbonic oxide, marsh gas, hydrogen and nitrogen, and in this order we will now examine them separately.

CARBONIC ACID.

Carbonic acid, chemically known as carbon di-oxide, is a colorless, non-combustible gas, having a feeble acid taste and a faint, pleasant odor. It is incapable of supporting either combustion or respiration, a burning match or taper being instantly extinguished if introduced into it, and an animal will speedily die if placed in same. Some authorities claim that it is not directly poisonous, death resulting therefrom merely because of the absence of oxygen, while others state it has a direct poisonous effect upon the system, the prolonged inhalation of air containing only a slightly increased amount having a distinctly lowering effect upon the vitality.

Carbonic acid is a heavy gas, being about 1½ times heavier than air, its specific gravity compared therewith being 1.529, and, because of its great density, it may be poured from one vessel to another much the same as a liquid. If a soap bubble be allowed to fall into a jar containing carbonic acid it will be seen to float upon its surface.

The power of carbonic acid to extinguish fire is very great, this property being taken advantage of in the construction and principle of many of the fire extinguishers in common use, which shows why it is best to have as little as possible of this substance in lighting and heating gases.

Carbonic acid is the gas used in making the familiar soda water, the bubbles rising and escaping therefrom being that gas. It is also the gas known to miners as "choke damp," from which there is great danger to life after mine explosions. Carbon and oxygen combine to form carbonic acid in the approximate proportions of 12 and 32 by weight; thus, in 44 pounds there are 12 pounds of carbon and 32 pounds of oxygen.

In commercial gases, carbonic acid is considered an impurity, and in their manufacture the aim is always to keep its percentage as low as possible, some gas managers going so far as to totally eliminate it by purification, though it is usually found in illuminating gas in amounts of from 2 to 4 per cent.

ILLUMINANTS.

As previously stated, the illuminants of gas so closely resemble ethylene that a description of that substance will suffice to give a practical idea of the light-giving portions of illuminating gases.

Ethylene, known also as ethene, and more commonly as olefiant gas, is a colorless gas having a somewhat pleasant, ethereal smell. It burns with a highly luminous flame, and can be used for purposes of illumination through small burners in much the same way as acetylene.

Carbon and hydrogen combine to form ethylene in the approximate proportions of 24 and 4 by weight; thus, in 28 pounds there are 24 pounds of carbon and 4 pounds of hydrogen. It is of very nearly the same weight as air, its comparative specific gravity being .971.

The "illuminants" of a gas form one of its most important component parts, being as they are those portions to which is due the illuminating value of lighting gases, such as coal gas, illuminating water gas, oil gas, etc., and to which is also due a very large amount of the heat-giving value of those gases, these illuminants in proportion by volume being by far the greatest heat-giving constituent.

OXYGEN.

Oxygen is one of the elementary bodies and is a colorless gas having neither taste nor smell. It is slightly heavier than air, its specific gravity being 1.1056. It is only slightly soluble in water, 100 parts of which dissolved but 4.10 of oxygen measured 0° C.

Oxygen is the most widely distributed and abundant element on earth, but it is of little interest in considering the composition of commercial gases, as it is contained in them in only very small proportions, usually from .2 to .4 per cent. in illuminating gases, and may be classed as an impurity, its presence being usually due to a small amount of atmospheric air finding its way in during the process of gas manufacture.

CARBONIC OXIDE.

Carbonic oxide, chemically known as carbon monoxide, is a colorless, tasteless gas, possibly having a faint odor, but upon this point chemists seem to differ. It burns with a pale blue flame, and is the gas which is seen burning on the top of hard coal, coke or charcoal fires. It is a little lighter in weight than air, its comparative specific gravity being .9678. It is exceedingly poisonous when inhaled, very small quantities present in air rapidly giving rise to headache and dizziness.

The poisonous action of this gas is due to its absorption by the blood with the formation of a bright red compound known as "carbon-hæmoglobin," and blood so charged appears to be unable to fulfill its function of absorbing and distributing oxygen throughout the system.

Carbon and oxygen combine to form carbonic oxide in the approximate proportions of 12 and 16 by weight; thus, in 28 pounds there are 12 pounds of carbon and 16 pounds of oxygen.

Carbonic oxide is of intermediate importance in coal gas, in which it is found in proportions of from 4 to 7 per cent., but in illuminating water gas of from 20 to 30 per cent., there being a still greater proportion in blue water gas, while in plain producer gas it forms the only combustible constituent. Carbonic oxide in percentage by volume is of comparatively little value as a fuel gas, having, volume for volume, only about one-fifth of the heat energy of "illuminants."

MARSH GAS.

Marsh gas, chemically known as methane, is a colorless, tasteless, inodorous gas, and burns with a pale, feebly illuminous flame. It is about one-half as heavy as air, its specific gravity being 0.558. Marsh gas is found in the free state in large quantities in nature, it being one of the products of the decompositions resulting in the formation of coal measures as well as petroleum. The name marsh gas has been given to this compound because of its occurrence in marshy places, owing to the decomposition of vegetable matter, the bubbles of gas which arise when marshes or the bottoms of ponds are disturbed consisting largely of marsh gas. It is also the gas known to miners as firedamp, and natural gas is chiefly composed of it, some of that found in the Ohio and Indiana fields being almost wholly marsh gas, though the California natural gases at Stockton and Sacramento contain much smaller percentages.

Marsh gas is composed of carbon and hydrogen in the approximate proportions of 12 and 4 by weight; thus, in 16 pounds of marsh gas there are 12 pounds of carbon and 4 of hydrogen. Marsh gas is one of the most valuable constituents of illuminating gases, coal gas containing from 35 to 40 per cent. and illuminating

water gas from 25 to 30 per cent. It is a most excellent fuel gas, and being contained in light-giving gases in large proportions, it constitutes an important heating element therein. Volume for volume it has about two-thirds the heating value of "illuminants."

HYDROGEN.

Hydrogen is one of the elementary bodies, and is a colorless, inodorous, tasteless, inflammable gas, burning with a pale blue, non-luminous flame, the temperature of which is very high. It is not poisonous, and may, therefore, be inhaled with impunity. Hydrogen is the lightest substance known, its specific gravity as compared with air being 0.0693, and it is but slightly soluble in water, 100 volumes of which take up only 1.93 volumes of hydrogen.

The fact that hydrogen is lighter than air is shown by opening a vessel containing it and turning the mouth upwards, when the gas escapes, and in a very short time no trace of it can be found, and if soap bubbles be made with hydrogen they will rise freely in the air. Hydrogen forms a very important part of almost all commercial gases, it amounting to from 30 to 40 per cent. and sometimes as high as 50 per cent of ordinary illuminating gas.

While hydrogen is usually considered a very hot gas, its flame temperature being high, it is of low heating value when compared volume for volume with certain other gases, it giving off during combustion only about the same amount of heat as carbonic oxide, which, as stated above, has only about one-fifth the heating value of "illuminants," though, because of its large volume percentage in the gases described, it forms an important part of the heat given by them. Hydrogen in burning unites with the oxygen of the air to form water.

NITROGEN.

Nitrogen is a colorless gas without taste or smell, and is slightly lighter than air, its specific gravity compared with that substance being 0.971.

Nitrogen will not burn, nor will it support the combustion of ordinary combustibles. It is not poisonous, but it is incapable of supporting respiration, and is one of the most chemically inert substances known. Nitrogen is contained in illuminating gases in proportions varying from 4 to 8 per cent., and may be classed an impurity, its presence being mostly due, as in the case of oxygen, to atmospheric air finding its way in during the process of manufacture.

One other elementary substance conspicuous in the manufacture of gas has so far been neglected by the writer, viz., sulphur; but as it, in its ordinary forms, is removed by purification, and is not usually considered in referring to commercial gases, a description of its combinations with our other elements is not deemed necessary for the purposes of this paper, as is also the case with ammonia, a compound of hydrogen and nitrogen, which is supposed to be removed from finished gases.

From the foregoing it will be seen that the composition of all such gases as are ordinarily used for domestic or manufacturing purposes may be classed under three distinct heads:

1. Illuminants; containing the light-giving portions of the gas.
2. Dilutents; hydrogen, marsh gas and carbonic oxide, all combustible, heat-giving gases.
3. Impurities: Carbonic acid, oxygen and nitrogen, all non-combustible substances. The valuable constituents are, therefore, the four substances: illuminants, hydrogen, marsh gas and carbonic oxide, the varying proportions of which determine the lighting and heating values of commercial gases.

Mr. Lowe, while reading the paper, performed many interesting experiments. Hydrogen, marsh gas, ethylene and carbonic oxide, the four gases wich compose ordinary coal gas, were exhibited in large glass bottles, and each gas was lighted in order to show the characteristics of its flame. The gases were then combined in the proper proportions to make commercial coal gas, and the flame produced combined with the flames of the component gases. "It seems strange," said Mr. Lowe in performing the experiment, "that these four gases, only one of which has any odor at all, should produce an illuminating gas that smells so bad. There are a great many combinations possible of hydrogen and carbon, over 200 in all. Some of the combinations have an abominable odor, and to that is due the disagreeable smell of our gas, coupled with the fact that a considerable amount of bi-sulphide of carbon is present. But the elementary substances, with the exception of ethylene, are all non-odorous, wherefore we might expect a pleasant-smelling substance instead of a bad one. Marsh gas would be a poor illuminant burning in a flat frame burner. The Ohio natural gases are almost entirely marsh gas; those in Sacramento and Stockton about 65 per cent. There is a popular fallacy that such a thing as stratification of gases occurs. You may stratify vapors, but there is absolutely no such thing as stratification of gases. Gases do not mix instantly and become an average composition. There is a certain rate of diffusion. Some diffuse rapidly, others slowly. Ultimately they become an average composition. Natural gases mix as perfectly as others. If you put natural gas in a holder and then put in manufactured gas they will take a certain time to mix, but they can be mixed quickly when they are going in—through the station meter, for instance."

CHARACTERISTICS OF CALIFORNIA PETROLEUM.

BY A. S. COOPER, State Mineralogist.

PETROLEUM oils from the different oil fields of California differ widely in physical characteristics and chemical composition. They may contain, chemically combined, one, two or three of the following elements, sulphur, oxygen and nitrogen, and in widely varying amounts, while in some rare instances these elements may be absent. Oils in the same stratum and a short distance apart may vary greatly. Frequently a well when it first yields will give an oil of a lighter gravity than that which it will yield when it has been pumped for some time.

We may, therefore, look upon California petroleum oil as containing the following substances in an unknown state or states of combination: Carbon, hydrogen, sulphur, oxygen, nitrogen and other substances in minute quantities; these combinations being very great in number and extremely complex.

The boiling point and melting points of the bitumens are altered very considerably by the presence, or even by the traces of, sulphur, oxygen and nitrogen. The presence of a greater or less amount of these substances during distillation has an influence on the distillate. Generally the larger the amount of carbon, sulphur, oxygen or nitrogen an oil contains, the greater its specific gravity, boiling and melting points.

California petroleum is a mixture of a large number of hydrocarbons, and a large number of compounds containing hydrocarbons, combined with sulphur, oxygen, nitrogen and other elements.

The sulphur compounds usually predominate, followed by oxygen, then nitrogen, and, last, the other elements in smaller quantities. These sulphur, oxygen and nitrogen compounds were formed at the time that the oil was distilled from carbonaceous rocks by the heat of metamorphism, or are substitution compounds formed subsequent to such distillation by the hydrocarbons coming in contact with these substances under different conditions. Oil when exposed to the air absorbs oxygen. When heated with the peroxides the peroxides are reduced to a lower state of oxidation. Petroleum when exposed to sulphur vapors absorbs them; when heated with the persulphides the persulphides are reduced to a lower state of sulphuration. From the above it can be seen that California petroleum is of a highly complex character, containing a large number of hydrocarbons and hydrocarbon derivatives. When the sulphur, oxygen, nitrogen and other elements are removed a number of the remaining hydrocarbons must be unsaturated, and unless these substances be removed from the crude oil before distillation, fractional distillation does not give a true index to the composition of the oil. Ultimate analysis is worthless to show the character of the oil.

All the hydrocarbons and their compounds with other elements in California crude petroleum are volatile. Some, such as benzine, are extremely volatile, whereas asphaltum volatil-

izes with great slowness. Natural gas is a volatile part of petroleum. Like coal the bitumens, oils and asphaltum, through decomposition, are constantly giving off carburetted hydrogen.

This decomposition is probably effected by acids, alkalies and other oxidizing agents forming oxygen compounds with the bitumens and liberating carburetted hydrogen.

Decomposition may also be effected by sulphurizing agents forming sulphur compounds with the bitumens and liberating carburetted and sulphuretted hydrogen. These oxidizing and sulphurizing agents are formed by metamorphism and other chemical reaction within the earth, and which came in contact with the bitumens. Carburreted hydrogen may also be generated from oil by heat. This gas is often found issuing from vents in the ground in California, having a temperature higher than the surrounding ground, sometimes as high as 90° F.

One of the reasons that California petroleum oil has such a high gravity is owing to the fact that the formation in which the oils occur is tilted and broken, permitting the escape of the gases. When California petroleum is evaporated by atmospheric influences, the sulphur, oxygen, and nitrogen compounds remain and are concentrated, and if the process is continued long enough solid asphaltum is formed. After asphaltum is formed evaporation proceeds with exceeding slowness. Heat accelerates evaporation. The evaporation from an oil tank built underground and kept at a temperature of 60° F. is far less than from a tank built above the ground and exposed to the sun's rays, which may often reach a temperature of 130° F.

If a petroleum oil having a specific gravity of 40° B. be exposed to the heat of the sun in a shallow pan it will decrease 20 per cent. in volume in a short time; the portion of oil evaporated being better for the manufacture of gas than the part remaining in the pan. This experiment is easily tried and very convincing. Notwithstanding this loss by evaportation caused by high atmospheric temperature, the oil producer stores his oil in dark colored tanks which are exposed to the blistering heat of the sun, and it is to be regretted his example in many instances is followed by the gas manufacturer. If the oil tank cannot be placed underground where the temperature is low and fairly constant, it should at least be shaded from the sun and whitewashed to decrease absorption of heat.

When a fresh supply of oil is emptied into a tank which contains oil which has been stored for some time, it should be introduced into the bottom of the tank. The fresh oil, being lighter than the oil already in the tank, has a tendency to ascend, and in doing so it dissolves the heavy oil and will not evaporate as rapidly as it would if placed on the surface of the heavy oil.

Advantage is taken of the fact that asphaltum is nearly an unalterable gum to make many constructions in which a plastic and unalterable cement is required. Usually California asphaltum contains from 5 to 9 per cent. of sulphur.

Some wells in California produce oils containing paraffine, but they are so valuable for producing illuminating oil that their use for gas making is prohibited.

At Baku, in Russia, a tract of land less than 20 acres in area has produced in 12 years 35,000,000 barrels of oil, and is still producing about 12,000 barrels per day.

On the Laguna Extension, or Zaca rancho, in Santa Barbara county, California, there are large deposits of bituminized sand exposed upon the surface. On any one of several 20-acre tracts at this place the dimensions of the exposures of the bituminized sand would show that it contains 8 million barrels of heavy petroleum of the consistency of molasses.

To make one barrel of that material must have taken 8 barrels of ordinary petroleum before evaporation, so that on each 20-acre tract is now the remains of 64,000,000 barrels of petroleum oil. The astonishing part of this is that it is seen upon the surface and is not hidden beneath. Therefore, in California as well as in Russia, there are probabilities of a very small territory producing immense quantities of petroleum oils. The case cited shows one at least of such places, and there may be, and doubtless are, many others of similar character where the oils are still hidden.

Unaltered rocks of California cover an area of over 40,000 square miles. Bitumens occur in all geological formations, from the putonic, metamorphic or igneous rocks, up to and including the quarternary. It is found saturating strata of sand and seamed shale, and as many as 10 beds of shale can be seen on the eroded sides of some of the anticlinal ridges of the Coast range. These sand beds are very irregular as regards their thickness and the distance intervening between them. Some are a few feet in thickness, while others exceed 400 feet, and the shales are from a few feet to over 500 feet in thickness.

When several sands are to be seen on the side of a mountain, or when they can be traced upon the surface of the earth by their outcrop, if bituminized at all, the bitumen will generally be in the geologically lower beds, and when a sand contains bitumen the underlying sand beds are also liable to contain bitumen. At the present time nearly all the wells that are being bored are in the vicinity of surface indications; to wit, oil seepages, outcrops of bituminous rock and gas blows, all of which are signs that the reservoirs of petroleum are leaking owing to insufficient cover. At present the wells are generally shallow, but they will increase in depth in time as they have done in other oil fields.

The day is not far distant when oil territory will be selected by geologists on account of favorable structure and position, irrespective of surface bitumens. The wells in this territory will have to be drilled to greater depths, but when productive will yield light oil. Owing to the large area and the thickness of the unaltered rocks, and the great thickness and the number of the oil sands in California, the yield of oil in California in future years will be enormous.

A comparison of the consumption of fuel oil with that of coal shows 3.33 barrels of fuel oil to be equivalent to one ton of good imported coal. Figuring oil at $1.40 per barrel, and coal at $7.50 per ton in San Francisco, it shows the cost of oil to be $4.66 as against $7.50 for its equivalent in coal. Moreover, the labor required to operate with coal is far greater than with oil, in most instances being nearly double.

The perfect cleanliness of fuel oil, and the ease and simplicity of supply and regulation, make it a most desirable substitute for coal. As long as coal remains at $7.50 per ton in California it cannot be expected that oil will fall below its present price; not at least for some time to come.

In the year 1899 there were 1,740,027 tons of coal imported into the State of California; to supplant this 6,794,278 barrels of oil will be required. As the supply becomes more permanent the uses of fuel oil will multiply.

The removal of the gasoline, benzine and illuminating oil leaves an oil with a high flashing point, which would be less dangerous to use in a locomotive and otherwise than a fuel oil of low flashing point. The removal of the water also improves the oil for fuel purposes, as it does not have to be evaporated by the fire.

The asphalts in the crude oil are objectionable for the manufacture of gas. When the asphalts are subjected to the temperature necessary to gasify the oil, sulphurous gases are formed (principally sulphuretted hydrogen), and as the asphalts contain a large percentage of sulphur these gases are formed in quantity and require a large amount of a purifier for their removal. The presence of asphaltum also fouls the checkerbricks in the superheater and carburetter in making water gas, and the retorts in making oil gas.

At present the market value of asphaltum is too high for it to be economically used for either the manufacture of gas or for fuel purposes. The large percentage of sulphur in natural asphaltums or in those obtained as a residue in the distillation of crude petroleum make them an undesirable fuel. During combustion with oxygen the sulphur combines with the oxygen to form sulphur dioxide. Sulphur dioxide in absorbing water, or the vapor of water, changes to suphurous acid. By

oxidation the sulphurous acid is changed to sulphuric acid which may lodge on the surface of the boiler and attack the iron, forming sulphate of iron. Through this action the sulphur contained in the asphalt is a cause of corrosion in boilers. Owing to the presence of sulphur the fuel value of asphaltum is small when compared with the other hydrocarbons contained in crude oils.

The time is not very far distant when crude California oil will not be used for the manufacture of gas. Distillates will be substituted for crude oil for the reasons given in this paper; therefore, it will be of interest to know what action distillation will have upon the crude California oils.

In Pennsylvania the upper half of the still is left exposed to the air to facilitate decomposition. During the first distillation of crude California petroleum oil, decomposition of any part of the oil should be avoided; consequently the stills should be completely bricked in so that the vapors will be kept fully heated until they escape to the condenser. In the manner of cracking as practiced in Pennsylvania there must be a great loss of heat from the exposed surface of the still.

The laboratory and practice show that the distilling, manipulating and purifying of crude California oil must be totally dissimilar and different from the methods in use in Pennsylvania, Canada and elsewhere. Most of the crude California oils should be distilled twice. From experiments made it would appear that the vapors of the lower hydrocarbons during distillation are contaminated by the decomposition of the sulphur compounds contained in the higher hydrocarbons, such decompositions being caused by heat. Usually the higher the boiling point of a distillate obtained during any one run of a still the greater the amount of sulphur compounds contained in the same. In distilling oils containing sulphur the main bodies of the sulphur compounds remain in the higher hydrocarbons. Owing to this action, by repeated distillation the sulphur compounds are generally eliminated to a great extent, but hardly ever completely, from the oil.

A distillate having a certain specific gravity, when distilled under atmospheric pressure from crude petroleum, may contain sulphur in notable quantity; whereas a distillate of the same specific gravity when distilled from the same crude petroleum oil in vacuo may be comparatively free from sulphur. This is probably owing to the fact that a greater temperature is required to vaporize the oil when under atmospheric pressure than in vacuo, this additional heat decomposing the sulphur compounds. At ordinary temperatures petroleum oil does not absorb sulphuretted hydrogen when collected on the surface of the oil.

If hydrogen at a high temperature, or in a nascent condition, is introduced into the vapors of the light hydrocarbons during distillation, the sulphur vapors which are formed by the decomposition of the sulphur compounds contained in the lighter hydrocarbons combine with the hydrogen and can be carried from the still; but if the hydrogen is omitted, the sulphur from the decomposition of the sulphur compounds combines with the hydrocarbons to form complex sulphur compounds which are removed with difficulty. It is supposed that, when in a crude state and not distilled, the lower hydrocarbons in the California petroleum do not contain sulphur compounds to any marked extent, but are sulphurized during distillation by the decomposition of the sulphur compounds contained in the higher compounds.

The asphalts obtained by the distillation of California petroleum contain from 4 to 7 per cent. of sulphur. Vapors of sulphur have a greater affinity for heated hydrogen, forming sulphuretted hydrogen, than for heated hydrocarbon vapors to form sulphur compounds. When hydrogen is in a nascent condition it will replace sulphur in the liquid compounds of sulphur and hydrocarbon by inverse substitution. The activity of this action is increased by heat. At 60° F., the action is very feeble, but at 200° F. the action is rapid, and at higher heats the action is still more rapid.

As has been stated above, California crude petroleum is composed of a number of hydrocarbons and hydrocarbon compounds, mutually dissolved one within the other, and having different boiling points. Owing to this they can be fractionally distilled so as to separate them into fractions having the following commercial names and physicial characteristics:

Crude California Oil, 26 deg. B. Distillates, Commercial Name.	Gravity — Approximate Baume.	Gravity — Specific Gravity.	Weight of 1 gal. in lbs.	Per cent Obtained, Approx.
Gasoline	75	0.6820	5.69	3
Benzine	63	0.7253	6.04	4
Illuminating	45	0.8000	6.66	13
Mineral sperm	38	0.8333	6.94	8
Gas distillate	28	0.8860	7.38	21
Light lubricating	26	0.8974	7.48	8
Neutral	23	0.9150	7.62	10
Heavy lubricating	21	0.9271	7.72	5
Valve Lubricating	15	0.9655	8.04	4
Asphalt	..	..	..	11
Loss	..	..	..	13
				100

The following are the percentages of the distillates obtained by the first distillation from many crude California oils:

Naphtha	traces to	15	per cent
Illuminating	6 "	27	"
Gas distillate	16 "	30	"
Lubricating	20 "	52	"
Asphalt and loss	7 "	25	"

In the first distillation the following are the temperatures at which the following distillates are distilled:

Crude naphtha	—— to	150°	C.
Illuminating distillate	150° "	300°	C.
Gas distillate	300° "	350°	C.
Lubricating	350°	——	

Owing to the highly complex composition and great diversity of California oils the above figures are to be considered only suggestive.

The Theory of Distillation by Steam.—Very many substances which distill only slowly or with decomposition can be quickly distilled and the decomposition averted if a current of steam is passed into the space above the boiling liquid or into the liquid itself. The latter is the better, for it gives a longer surface from which the vapor may come off, and also agitates the liquid so that in case there is any sediment it will not burn fast to the bottom of the still. Crude petroleum may be cited as a substance volatile with steam.

The reason why steam helps distillation may be explained by Dalton's law (the pressure, and consequently the quantity of vapor which saturates a given space, are the same for the same temperature, whether this space contains a gas or a vacuum).

Now, as steam carries out from the still the vapor of the boiling petroleum, and thus allows more vapor to take its place, this explains the increased speed of the distillation by steam.

The vapor of the petroleum being removed, the liquid is as free to evaporate as if no steam were present—i. e., as if a vacuum was maintained; but it cannot be said that distillation with steam is the same as distillation in a partial vacuum. It only gives the same result as the latter. The decreased amount of decomposition may be explained by the vapor being quickly removed from contact with the superheated liquid and the sides of the still.

Why would not carbonic acid, hydrogen and other gases do as well as steam? When any of the gases, or their component parts, affect the petroleum it is manifestly inadmissible. For instance, sulphuretted hydrogen would sulphurize the petroleum, and the oxygen of air would oxidize the petroleum. Many gases could be used if they were practically condensible.

The volume of steam used is immense and condenses to water, which occupies1-1698 of the volume of the steam. Thus

steam may be used to aid in the distillation of petroleum, which is not soluble in or decomposed by water.

Having finished reading the paper, Mr. Yale added: The production of oil is increasing in this State, but not so fast as is ordinarily reported. You hear all sorts of reports, but last year when I went to the officers of the oil companies I found that the ordinary tales of the street were very much reduced. A report of four or five million barrels fell to between two and three. This year the output will be greater, for many wells have become productive which were not the year before.

SOME NOTES ON LARGE TYPES OF GAS ENGINES.

BY J. B. CROCRETT.

BRYAN DONKIN, in speaking of the early types of combustion engines, says that "the earliest attempts to obtain motive power from heat were made by igniting inflammable powder and utilizing the force of the explosion thus generated. As a source of energy this combustible powder was the first agent used; it preceded the production of coal gas or of steam. Strictly speaking, cannons are the oldest heat motors, and the principles on which they are constructed are identical with those of internal combustion engines. Heat is applied to explosive powder, and the expansion of the powder furnishes the motive force to propel a ball forward. In modern heat engines a piston takes the place of the ball. In the early days of mechanical science the energy shown in the projection of a cannon ball seems to afford a simple solution of the problem how to obtain power and motion by heat. But the power produced by exploding powder in a cannon could not be used for practical work, because it was not generated continuously and regularly. To apply the expansive force of the gases given off during combustion, the combustible was exploded in a closed vessel and made to act upon a piston. These early combustion engines were the forerunners of modern gas motors, in which the power is also obtained by explosion. But though they were introduced nearly 100 years before the first steam engine, they were soon abandoned because it was found impossible to control the power generated. Steam was easier and safer to work with, and for more than a century explosive engines were wholly relinquished."

He further says that Abbe Hautefeuille, the son of a baker at Orleans, was the first to obtain power, and had the honor of designing not only the first engine worthy of the name, but the first machine using heat as a motive force and capable of producing continuous work. But in 1680 Huyghens was the first to employ a cylinder and piston working engine, which was exhibited to Colbert, the French Minister of Finance. And so on, to Barber and others, until we come down to Street, who, on May 17th, 1794, made a great step in advance by using inflammable gas which was exploded in the cylinder and drove up a piston by its expansion, thus affording the first example of an internal combustion engine. The gas was obtained by sprinkling spirits or turpentine or petroleum at the bottom of a cylinder and evaporating by fire beneath. The up stroke of the piston admitted a certain quantity of air which mixed with the inflammable vapor. The flame was next sucked in from a light outside the cylinder through a valve uncovered by the piston and forced down the piston of a pump for raising water. In this engine many modern ideas were foreshadowed, especially the ignition by external flame and the admission of air by the suction of the piston during the up stroke; but the mechanical details were crude and imperfect.

From that time on a great many improvements were made which would be almost too tedious to mention in a paper of this length. Many of these were made by Lebon, Wright, Drake, Barsanti, Matteucci, and in 1860, when Lenoir and others took the matter up, gas engines had attained much greater importance. The matter was finally taken up by Sir William, then Dr. Siemens, who got up an engine on a regenerative plan. A few years later an engine was brought out by Kinder and Kinsey, which closely resembled the Lenoir, but presented no new features, and which consumed about 70.5 cubic feet of gas per horse power hour. The defect of most of the older engines was in the large consumption of gas in proportion to the work done.

Mr. Donkin, in his work on gas engines, says that in both the Lenoir and Hugon engines the pressures in the cylinder were always low and difficult to maintain, and this showed that the pressure generated by the explosion alone was insufficient and must be increased by a previous compression of the charge. Time was also lost in obtaining an explosion, and the heat, applied too late to the gas, was speedily dissipated—some of it going to heat the jacket water and some being discharged at the exhaust.

M. Beau de Rochas, a French engineer, was the first to formulate a complete theory of the cycle of operations which ought to be carried out in a gas engine to utilize more completely the heat supplied. Four conditions were laid down by him as essential to efficiency:

1. The largest cylindrical volume, with the smallest circumferential surface.
2. Maximum speed of piston.
3. The greatest possible expansion.
4. Highest pressure at the beginning of expansion.

The construction of the gas engine was meanwhile developed in a different direction. As it was seen that the expansion of the engine was insufficient, an attempt was made to improve it by using a free piston, giving in theory unlimited expansion. In 1863, Otto and Langen took out patents by which they proposed to construct an engine with the vertical cylinder open at the top, containing two pistons and piston rods, one above the other. By having the two pistons it was intended to break the force of the explosions, for the idea has not yet been abandoned that the shock was injurious to the efficiency of the engine. With the advent of the Otto gas engine a new era began. Until the appearance of this motor, in 1876, not one of the many engines produced had utilized the cycle of operations, indicated many years before as the best and most economical by Beau de Rochas. It is to Otto, the German engineer, that the honor belongs of having first produced a practical working gas engine, using compression and giving an economical cycle of operations.

The Otto engine was brought out at a time when, in the competition between gas and steam, the balance inclined so much in favor of steam that it seemed possible that gas engines would be driven altogether from the field. Few engines at that time were more ingeniously constructed than the Otto, and even now it is one of the most economical. More than 30,000 engines were sold in about 10 years, and over 35,000 engines, with a total capacity of 150,000 horse power, had, up to 1892, been constructed by them.

In a paper of this length it would be almost impossible to take up comprehensively the different types of English, French, German and American engines, but I have attempted in a way to give you a short history of the best known engines up to that period. But before closing this portion of the paper I would like to read what Mr. Clerk says:

"From the considerations advanced, it will be seen that the cause of comparative efficiency of the modern type of gas engines over the old Lenoir and Hugon engine is to be summed up in one word, compression. Without compression before ignition an engine cannot be produced giving power economically and with small bulk. The mixture used may be diluted, air may be introduced in front of the gas and air, or an elaborate system of stratification may be adopted, but without compression no good effect will be produced. The proportion of gas to air in the modern gas engine is the same as was formerly used in the Lenoir, the time taken to ignite the mixture is the same, the only difference is compression. Combustion, or rather the rate of inflammation, is indeed quicker in the modern

(Continued on page 67.)

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EDITORIAL.

IN A COMMON CAUSE.

Some three years ago the manager of a large gas company on the Pacific Coast observed, in discussing the relations between gas and electricity, that they would never have anything in common, that they were natural enemies and always would be so, and that, so far as he was concerned, he cared to know nothing about electrical methods, for they must ever be alien to his business. Three months ago this same manager, whose company sells nothing but gas, and that in hard competition with a water-power electric plant, gave expression to a different opinion. "While," he said, "we are still fighting electric lighting with all our energy, we have learned that the more familiar we become with the details of the business of our electrical competitors the more proficient we become in the management of our own affairs. My own conviction now is that no gas manager can have too intimate a knowledge of electric lighting and power methods."

These words are true, but their force lies beyond the mere commercial profit that accrues to the gas manager who knows enough about electric lighting to swerve a wavering consumer to his side of the line by reason of alleged electrical vagaries; or, viewing the matter from the other standpoint, it is well for the electric-light man to familiarize himself with the gas business, but not that this information may enable him to the more glibly malign the incandescent gas mantel, for instance. A mutual knowledge of the other's engineering details is broadening and expansive, for each can give interpretation to the other's methods that will not occur when viewed from the single point of observation.

From the standpoint of generating plant, every engineering advantage seems to be arrayed on the side of the gas works, for, speaking in generalities, the generation of a product under conditions enabling the operation of units under full load at all times, and the storage of this product without losses and its utilization to meet the peak load, presents conditions that are truly ideal to the electric station engineer. But the high-pressure distribution so easily effected at comparatively slight expense in electrical work fully compensates for the disadvantages suffered by electricians in plant arrangements, for, with their cumbersome and expensive mains, the gas men have their turn at being envious of the superior methods of their competitors. The ultimate modes of application of the two systems are, however, nearer to a level, and honors between them are easy.

There is no error in the statement that gas-works engineering and electric-station engineering are in many regards developing along common lines. The electric storage battery, patterned in reality after the gas-holder, enables the dynamos to be run at maximum efficiency regardless of the station load, but in this the electrical engineer only accomplishes that which has long been regarded by the gas engineer as commonplace. Then the storage battery reduces the size of the dynamo installation materially, but that, too, is an old, a very old, story in gas works practice. In fact, the gas works is inherently free from the seemingly interminable troubles that beset the electric station engineer, who has ever struggled to subjugate the fractious conditions so happily summarized in a single but distressing term—load factor. The gas man contemplates the on-coming of winter with serenity, for shorter days mean increased use of gas for lighting at the time when cooler weather relegates the gas stove to the storeroom and resurrects the coal stove with its greater warmth. But no such good fortune awaits the electrician, who watches the advent of winter with dismay, for it brings an overlapping of lighting and power loads, with only, say, a mouse-power in electric fans here and there in summer to compensate. Thus it is that ofttimes some of his investment in boilers, engines, dynamos and distribution is earning revenue for but a hundred or so hours a year. Nor does any solution of the difficulty seem possible unless one's faith in human ingenuity prompts the thought that some day when electricity is made direct from coal, just as coal gas now is, the coal battery may deliver electrical energy in the very accommodating fashion of the electric storage battery. Then may the gas men exalt no more because of superiority and simplicity in generating methods.

And now the gas man, realizing from his observation of electrical and other engineering developments that high-pressure distribution is of prime necessity to its efficient delivery of service over large areas, has turned his energies in that direction and much may be expected therefrom, for a fourfold pressure enables a double quantity of gas to be sent through a pipe of given diameter. Mr. F. H. Shelton, of Philadelphia, has recently told* of the progress that has been made in this direction. At Oakland, Cal., gas is transmitted a distance of eight miles through an 8-inch pipe line with an initial pressure of

*Proceedings International Gas Congress, Paris, September 4, 1900.

five pounds per square inch and a final pressure of four inches with a loss of one-quarter candle in the illuminosity of the gas. At Chicago gas is transmitted four miles through a 4-inch pipe without material loss in candle-power, the pressures being ten pounds initial and 7½ inches final. At Danbury, Conn., enriched water gas is transmitted three miles through a 20-inch pipe at an initial pressure of 20 pounds per square inch with no loss in lighting power. The use of Pintsch gas in train lighting confirms this result. Mr. Shelton states that the mechanical difficulties in connection with gas distribution at these pressures have been solved and, similarly, no difficulties pertaining to the gas itself have been encountered, for while the lighting power is affected by the compression of coal gas or water gas to a pressure of 200 pounds per square inch, the use of more moderate pressures is less liable ts do so. It is along this line that gas engineering is entering a field of development that will be as marked as were the influences exerted by the introduction of alternating-current apparatus in electrical development.

One other point to show the further common trend of gas and electrical interests. For years each progressed in the even tenor of its way until the Welsbach mantle gave gas companies their most effective weapon for use against electric lighting. Then came the Nernst incandescent electric lamp, which may be viewed as a most clever and ingenious adaptation of principles of the Welsbach burners to electrical ends. Though the Nernst lamp has not entered the industrial stage of its usefulness as yet, its early commercial perfection is probable*, and its advent will mark a doubling almost in the efficiency of the incandescent electric light.

These, then, are a few of the very many reasons why the electric station engineer should familiarize himself with gas methods, and why the gas works engineer should lose no opportunity to acquire information concerning electric plants and systems. The two industries are of a common parentage—power and lighting—as these columns have so often indicated, and every effort toward estrangement between them is unnatural, short-sighted and bigoted. And the mature conviction and utterances of such a nature as that of the gas works manager first quoted are signs of the times that are not to be disregarded.

TESLA ROTATING FIELD PATENTS SUSTAINED.

Judge Townsend, of the United States Circuit Court for the District of Connecticut, rendered a decision on August 29th sustaining the Westinghouse Electric and Manufacturing Company in its suit against the New England Granite Company for alleged infringement of the Tesla polyphase patents Nos. 381,968, 382,279 and 382,280, granted in 1888.

These are the fundamental Tesla polyphase patents, and in granting the injunction prayed for the court orders an accounting as to all the claims in suit. A synopsis of the argument of the case can be found in the *Electrical World and Engineer*, Vol. XXXIV, page 782, Nov. 18, 1899.

*See *Electrical Review* (N. Y.), Vol. XXXVII, No. 12, page 277.

SOME NOTES ON LARGE TYPES OF GAS ENGINES.

(Continued from page 65.)

engine, because the volume of the mixture used at each stroke is greater, and yet the time taken to completely inflame the mixture is no more than the old type. The cause of the sustained pressure shown by the diagrams is not slow inflammation (or slow combustion, as it has been called), but the dissociation of the products of combustion and their gradual combination as the temperature falls, and combustion becomes possible. This takes place in any gas engine, whether using a dilute mixture or not, whether using pressure before ignition, and indeed it takes place to a greater extent in a strong explosive mixture than in a weak one.

"The modern gas engine does not use slow inflammation (or slow combustion, if the term be preferred), but in working, as it is intended to do, completely inflames its gaseous mixture under compression at the beginning of a stroke. By complete inflammation is meant the complete spread of the flame throughout the mass, not burning or combustion. If by some fault in the engine or igniting arrangement the inflammation is a gradual one, then the maximum pressure is attained at the wrong end of the cylinder, and great loss of power results.

"Compression is a great advance on the old system; the greater the pressure before ignition the more rapid will be the transformation of heat into work by a given movement of the piston after ignition, and consequently, the less will be the proportion of loss of heat through the sides of the cylinder. The amount of compression is, of course, limited by the practical consideration of strength to the engine and leakage of the piston, but it is certain that compression will be carried advantageously to a much greater extent than at present. The greatest loss in the gas engine is that of heat through the sides of the cylinder, and this is not astonishing when the high temperature of the flame in the cylinder is considered. In larger engines, using greater compression and greater expansion, it will be much reduced. As an engine increases in size the volume of gaseous mixture increases as the cube, while the surface exposed only increases as the square, so that the proportion of volume of gaseous mixture used to surface cooling is less the larger the engines becomes. Taking this into consideration it may be accepted as probable than an engine of about 50 indicated horse power could be made to work on 12 cubic feet of coal gas per indicated horse power per hour, or a duty of about 32 per cent."

The advance of the gas engine was much more rapid, and had come into more general use in Europe than in the United States, because, quoting from a paper* read before the American Gas Light Association, by Geo. G. Ramsdell, of Vincennes, Indiana, on October 14, 1880, he speaks of the purchase of a 17-horse power engine of the Otto, silent type, which he describes as somewhat in the nature of an experiment, as no gas engine larger than 7-horse power had ever been used in this country. But since that time, within the last 10 years, the development of the gas engine has been enormous, and its rapid introduction for all sorts of purposes has been astonishing. When a gas engine of 100 horse power had been placed in actual use it seemed as though the limit had been reached for that particular engine, but now we know of engines of 650 horse power being in operation, and the Westinghouse people are constructing a 1,500 horse power engine.

During my recent visit to the East I very thoroughly inspected several engines of large horse power varying from 90 to 650, the latter of which is now in operation running a dynamo which is direct connected at the works of the Westinghouse Electric and Manufacturing Company in East Pittsburg, Pa. I do not see that I can give a better description of this engine than that printed in the "Gas Engine," of April, 1900, written by George Westinghouse, and which describes the operation of the engine as follows.

*See *American Gas Light Journal*, Dec. 2 1880, page 245.

"Taking one cylinder of a three cylinder gas engine as an example. When the piston is at the top of its stroke and begins to move downward it draws in a cylinder full of a mixture of gas and air. On the return stroke this charge is compressed into the clearance space between the top of the piston and the cylinder head. The piston having reached the top of its compression stroke, the charge is ignited by the spark formed by opening an electric circuit in the clearance space, causing an explosion, which drives the piston downward on its working stroke, the burnt gases being expelled through the exhaust on the return stroke, which, when completed, brings all the parts of the engine in position to repeat the same cycle of operations. The shaft which carries the exhaust valve is driven by gears from the main shaft. Each exhaust cam works against a roller carried on the free end of the guide lever. The exhaust valve has a long stem projecting downward and resting on a hardened steel plate on the upper side of the guide lever. The spring surrounding the stem serves to hold the exhaust valve to its seat and the stem in contact with the guide lever. From the exhaust cam shaft a horizontal shaft with beveled gears leads to the opposite side of the engine engaging with a vertical shaft, which in turn drives the upper cam shaft. Incidentally the vertical shaft carries the governor. The upper cam shaft carries two cams for each cylinder, one engages against a roller on the end of the horizontal lever. As the throw side of this cam comes uppermost, the opposite end of the lever depresses the stem of the inlet valve, opening the latter for the admission of the mixture of gas and air. A spring on the stem of the inlet valve furnishes a means for closing it and keeping the cam and roller always in contact with each other. Immediately adjacent to the inlet valve cam is the igniter cam, which at the proper instant operates a horizontal plunger working through the guide to break the electric current through the wire at the terminal of the igniter.

"The cylinder heads and the upper end of the cylinder are thoroughly water jacketed, as, owing to the extreme heat to which these parts are subjected, they would soon become red hot if no means were provided to keep the temperature down.

"The gas and air enter the mixing valve chamber by separate inlets, in proportionate amounts, which can be fixed by the attendant, and the mixture is conducted through a distributing chamber to the port leading to the cylinder head in which is the inlet valve. To make a complete cycle the following are the four steps:

"1. Induction.—The piston is on its downward stroke, the inlet valve is open and the charge of gas and air is being drawn into the cylinder. The exhaust valve is closed and the inlet valve will close just as the piston reaches the limit of its downward stroke.

"2. Compression.—The piston is on its upward stroke; both valves are closed and the charge of gas and air is being compressed into the clearance space.

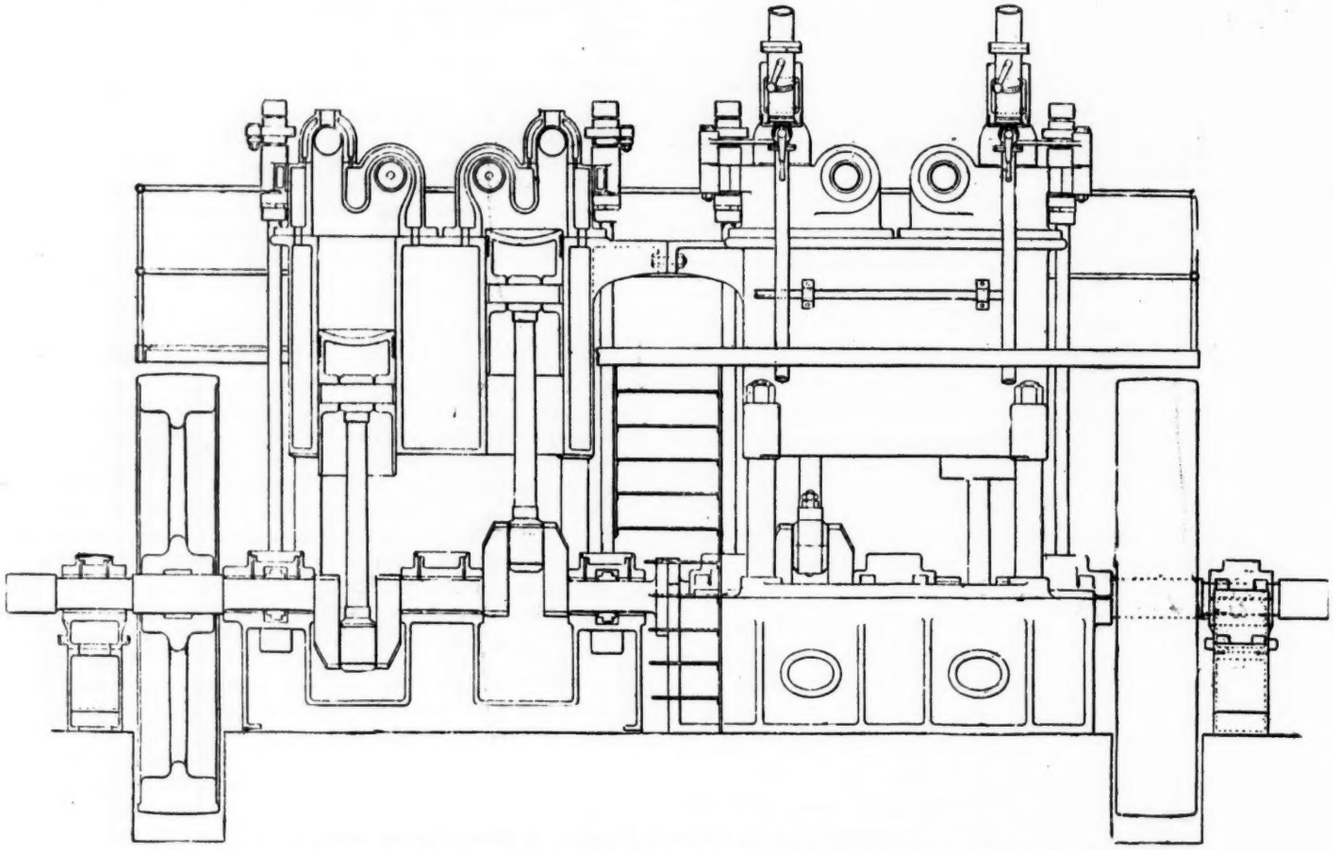

FIGURE 1.—ELEVATION OF 300-HORSEPOWER UNION GAS ENGINE FOR THE SAN FRANCISCO GAS AND ELECTRIC COMPANY.

"3. Ignition and Expansion.—The piston has reached the upward limit of its compression stroke, the crank is just passing its upper center and both valves are still closed. Shortly before this the igniter cam has brought the igniter terminals in contact, completing an electric circuit. Just at this instant it releases them, and they fly apart, actuated by a coiled spring in the guide breaking the circuit and forming a spark which ignites the charge. An immediate rise of pressure occurs and the piston is forced downward by the expansion of the burnt gases, both valves remaining closed until just before the completion of the stroke when the exhaust valve opens.

"4. Exhaust.—The piston is ascending, forcing out the spent gases through the now open exhaust valve and the exhaust pipe. The exhaust valve closes as the piston completes the stroke, bringing everything in readiness to repeat the cycle.

"The Westinghouse gas engine claims to have no competitor in regulation. The frequency of the impulse of the Westinghouse gas engine is the same for all loads, and the relative

proportions of gas and air remain constant, but the amount of the charge admitted to the cylinder and the consequent strength of the impulse are graduated exactly to the power required. By this system is obtained a nicety of regulation that is equalled only by the best types of automatic steam engines. The regulation of the Westinghouse engine is such that an engine direct connected to a dynamo will supply intermittent power for elevator service, and at the same time furnish an electric lighting system with perfect steadiness, and, what is perhaps still more exacting, run alternating current dynamos in multiple.

"The governing apparatus makes it possible to determine accurately the best proportions of gas and air to be used. At the top and bottom of the mixing valve chamber are horizontally moving levers with pointers swinging over graduated arcs. The upper lever controls the gas supply and the lower one the air supply. The ratio between the readings on the two scales, with the levers in any fixed position, shows exactly the proportion of air and gas in the mixture supplied to the cylinders. When the engine is running on a steady load, if one mixing-valve lever is moved backward and forward while the other remains stationary, the regulating valve stem will be seen to move up or down as the mixture becomes less or more efficient, indicating that a greater or less quantity is being used.

"An automatic starter is used in connection with Westinghouse gas engines. It consists of a small air compressor driven by the engine, which forces air into iron tanks, maintaining a supply which is kept in readiness for starting at any time. Three or four revolutions with the air pressure are sufficient for starting. The entire operation is strictly automatic and can be accomplished by one attendant without assistance."

The Union Gas Engine Company of San Francisco, is manufacturing gas engines on a large scale, but on a little different principle. It makes engines having one, two, three or four cylinders, as the necessities of the case require, each cylinder being independent of the other, and which can be shut off as the occasion may require. This system seems to meet with the approval of E. W. Roberts, M. E., who, in a paper on gas engine economy written for the "Gas Engine," says:

"It is not realized by every gas engine manufacturer that the advantages of the multiple cylinders are numerous. In the first place, an increase in the number of cylinders is conductive to steady running, as is generally admitted. The decrease in the necessary weight of the fly-wheel is not only of advantage in the saving of iron, but it also reduces the friction of the engine to a marked degree, and consequently increases the mechanical efficiency of the engine. In a multiple cylinder engine there are opportunities for balancing which are lost sight of by the majority of designers, and much has been done in this line in a hit-and-miss sort of a way. There is much literature on the subject of balancing, and very few writers agree as to proper methods. In fact, the gas engine builder quite frequently has derived an empirical formula of his own which gives results that are, in his estimation, good enough, but by no means perfect.

"There is also a chance for improvement in the handling of the water that passes through the water jacket. In factory tests it has been found that the best results were obtainable when the temperature of the water leaving the water jacket was 150° F., this temperature varying in different engines. But the writer has yet to see a single gas engine construction sheet in which this fact is mentioned. In fact, no attention whatever is paid to the temperature of the water jacket after the engine leaves the factory. Now, why should this be? Is it because the engine is the motive power for the ignorant or the indolent? The writer admits that this matter does not assume great proportions in the engines of small dimensions; but the question arises: 'Would it not pay to employ a temperature regulator on the engine that would control the temperature of the engine cylinder by means of the water supply?' It would be absolutely useless to leave this regulation to the engineer unless the engine were operating under a comparatively constant load, for with a diminution of the load the water supply should be decreased, and vice versa."

In these notes which I have collected I have as far as possible taken the history and experience of other people. In making a personal investigation recently of the gas engine my primary object was to ascertain, if possible, whether the San Francisco Gas and Electric Company would be justified in displacing the steam engines which it has at present in use, and which are now running our dynamos at the electric station known as station C, and which aggregate about 3,500 horse power. During the investigation I found that the engine of 650 brake horse power, running the Westinghouse shops with a direct connected dynamo, was running on from 12 to 14 feet of natural gas, which contains 1,000 B.T.U. One of the most important things for us to ascertain in this connection was whether illuminating gas containing from 635 to 700 B.T.U. would give the same results, using approximately the same amount of gas. This question apparently was not understood at first. At Long Branch, N. J., the Westinghouse people had put in a 280-horse power engine, which was operating with a gas of about 650 B.T.U., and which operated a belt-driven dynamo. In figuring the diameter of the cylinder sufficient allowance was not made for the difference in the heat units and considerable trouble was experienced from that cause. But in a short time this was overcome, and at present the engine is running in a most satisfactory manner. I stood for a long time watching the regulation of this engine and found that it ran on a light load almost as well as on a full load, as far as

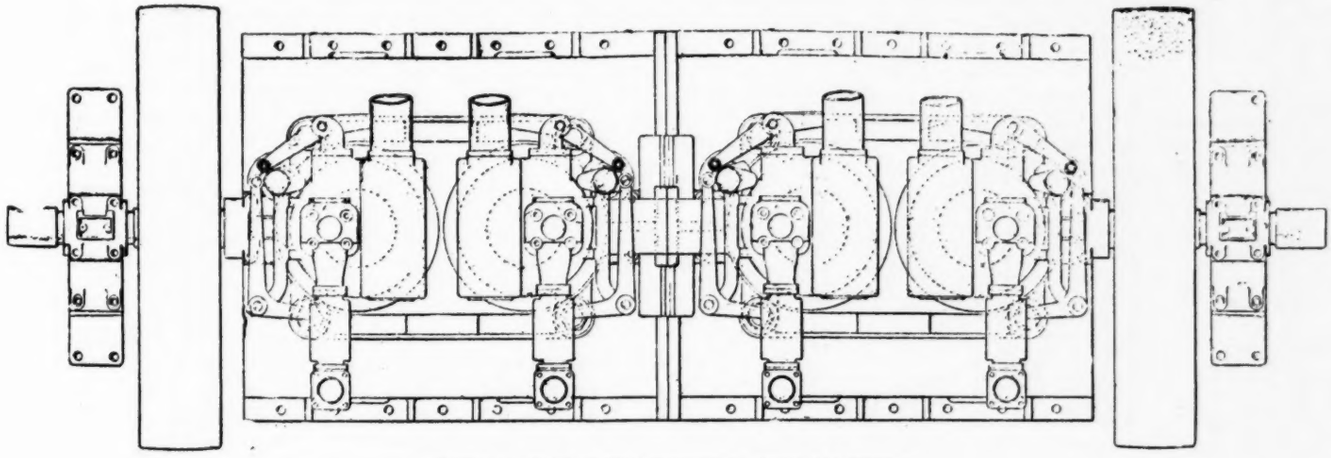

FIGURE 2.—PLAN OF 300-HORSEPOWER UNION GAS ENGINE.

regulation was concerned, the only apparent difficulty being that the engine back-fired with a loud report once or twice, but did absolutely no damage. The noise from the exhaust had been muffled so that it was not objectionable in the least degree, and the amount of gas consumed was from 18½ to 19 cubic feet per horse power hour.

In the office building of the United Gas Improvement Company there are also two gas engines of 90 horse power each direct connected to dynamos which run the elevators and also furnish light for the building, and I am told that their operation is very satisfactory, and that their regulation is so complete that the running of the elevators at the same time with the lights does not seem to make any material difference. The consumption of gas by these engines is about 18½ cubic feet per horse power hour; but the largest and best of all the engines was the 650-horse power engine at East Pittsburg, which impressed me very much with its steadiness and the silent manner in which it ran.

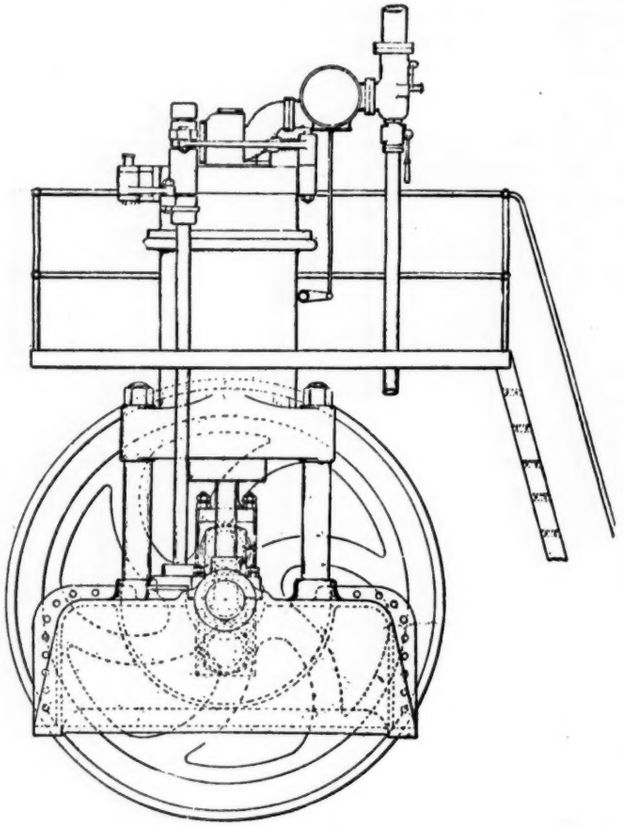

FIGURE 3.—TRANSVERSE SECTION OF 300-HORSEPOWER UNION GAS ENGINE.

The Union Gas Engine Company, of San Francisco, has never built an engine larger than 150-horse power, but without doubt the principle of the engine is good as well as the workmanship and they have shown great intelligence in the handling of it. For these reasons we have given the Union Gas Engine Company an order to build a 300-horse power engine with 4 cylinders. This engine is to be direct connected to a 200 k. w. generator, running at a speed of 200 revolutions per minute.

I am satisfied in my own mind that, with the great improvement made in the gas engine, it will finally supersede all other types of engines which are used for purposes of this sort. With a consumption of gas not to exceed 20 cubic feet of gas per horse power hour, with a regulation guaranteed within 2½ per cent. and the ease and economy with which the gas engine can be started or shut off at a moment's notice, and the saving in cost of attendance, I do not see how any other engine known at the present time can compete with it. In addition to that, even in other places, such as mining camps and factories where there is no gas manufactured for illuminating purposes, a cheap fuel can be made, which is adapted for the use of these engines, and although these fuel gases contain only about 150 heat units as against 650 in ordinary illuminating gas, thus requiring from 4 to 5 times the amount of gas, they can be manufactured so cheaply that in the long run it may be better to use them where circumstances warrant than to use the regular illuminating gas. A great many engines using fuel gas are in operation in the mines of Arizona, New Mexico and Mexico, and according to all the reports from these places are giving eminent satisfaction.

Therefore, in conclusion, I would say, from what I have seen and know, that if I intended to install a new plant for operating electrical dynamos, hoisting works or anything of that sort which required an engine within the range of the present development, I should not hesitate a moment to put in a gas engine.

During the discussion of Mr. Crockett's paper before the Pacific Coast Gas Association, W. J. Casey, president of the Union Gas Engine Company, stated in reply to inquiries propounded, that the engine which his company is building for the San Francisco Gas and Electric Company is a slight departure from the usual construction in that it is a four-cylinder vertical engine. Each cylinder is a separate engine and can be disconnected at any time for repairs to one of the cylinders, if necessary, or for the purpose of saving fuel under reduced load. Each cylinder has its own separate governor. The four-cylinder engine is really two double cylinder engines bolted togther. The crank-shaft is divided in the center and connected by flanged couplings in the same manner as in large marine engines. The bases of the frames are separate and are bolted together, the object of this construction being that, in the event of wanting to run generators from both sides of the machine, probably at different speeds, it can be accomplished by simply taking out the bolts from the couplings. The governors are placed on top of the engine and stand vertically in order to make them very sensitive. The valves are balanced by a balance placed on the horizontal shaft that works them. The governor is above the shaft. It is a double-valve governor, and graduates the charge in proportion to the amount of energy needed. Gas is brought in from the top and air from the bottom, each has its own regulator or governor. Inlet and exhaust valves are separate. Both are on top of the engine, as are all the working parts that need attention. By having four cylinders there is an impulse on every half revolution, just as in the case of a double acting steam engine. There are no loose joints. Everything is regulated when the engine is first set up. It is so regulated that the charges will fire regularly, no two at the same time. The two fly-wheels are eight feet in diameter and weigh 6½ tons each. The regulation will be within 1½ per cent. and the consumption of 650 B. T. U. gas will be about 16 or 17 cubic feet per horse power hour.

Another feature is that there is no residue left in the engine after each explosion. In old types of gas engines there was always a residue left in the head of the engine after each explosion, so that when the piston went down it mixed with the fresh charge the burned products that had not been expelled from the last charge. Now each charge is purely a fresh mixture. The gross weight of the engine for the San Francisco Gas and Electric Company will be about 80,000 pounds and its length will be about 24 feet. It starts, as Mr. Crockett has said, by simply opening a lever. The shaft is 7 inches in diameter in the bearings and 8 inches where it goes through fly wheels. The stroke is 22 inches and the connection rod brasses are of the same type as in marine engines. The cylinders are united at the top by a flange and bolted together to keep them rigid.

If desired, the engines can be disconnected at the coupling in the center of the shaft, enabling either engine to be run separately. This would necessitate the shutting down of the engine for a half an hour or so, as the bolts in the coupling are driven in with a sledge and in addition, there is a key going through both sides of the coupling. No information is available as yet concerning the consumption of gas when the engine is running empty.

INTRODUCING GAS STOVES*.

BY JOHN A. BRITTON.

THE development of the gas stove as a factor in gas consumption is a most interesting study to the gas man of to-day, and, viewed from the standpoint of 25 years ago, a transformation hardly to be credited. That gas companies, staid, conservative and gregarious, should have become venders of merchandise must cause the dry bones of our defunct predecessors to rattle alarmingly, and yet it is to the credit of the brain and brawn of the men of today that, instead of supinely sitting enthroned in the austereness of their dignity as purveyors of gas, they refuse to permit their light to be hid under an electric light bushel, but have set their torches on the highest pinnacle of civilization, the homes of our land, and have brought peace, cleanliness, order and contentment to such homes by lighting the fires upon their hearthstones with the torch of gas.

The manner in which this has been accomplished would be, if written, the most interesting volume ever contributed to gas literature, and yet today futile efforts to increase gas sales are being made which are due largely to the lack of knowledge, although the deep-seated ideas of some ultra conservative managers, that it is more profitable to attend only to the lighting problem, or to fight the inroads of electric promoters, may be held responsible for efforts which avail nothing.

It is a safe assertion that no gas company has ever been financially benefited by the absorption or creation of an electric light adjunct and also a safe assertion, if the amount of capital so invested had been employed in developing the multifarious uses to which gas may be applied, that the general public would have been benefited by large reductions from the present selling price in localities where such creation or absorption has taken place.

So much for an introduction, and now to the subject of this paper.

The methods of introducing gas stoves are as numerous as the locations in which they are sold. Time and money have been used with prodigality, in few cases with good results, in most attended with dire failure and consequent reactive depression affecting future developments. A discussion of the best method should be based upon the skeletons of disaster that line the road to success. Why capital should be invested in this branch of our business is one of the first questions to be asked and answered. How it should be invested, what companies have done, and what results have been obtained are the next reasonable inquiries. It is the purpose of this paper to attempt to answer all of these from the standpoint of experience, observation and results, both successful and otherwise.

The enterprising business man, having an article to sell, devotes his thoughts to the best method of presenting it attractively to his patrons; and that, too, in all phases, viewed not only from the standpoint of cost to the consumers, but also of utility and means of attracting attention as well as maintenance of its standard, placing it above possibility of competition.

First, as to cost to consumer. This in our case involves not only the commodity itself but the vehicle for the use of the commodity, and in dealing with consumers a barrier is usually built by the high cost of either the commodity or the vehicle.

The first essential is the cost of the commodity. The maintenance of high priced gas serves as an estoppel to its general use, and is the cause of the failure to establish profitable gas sales for fuel. The maintenance of a plant and distribution expenses are the largest factors in produce cost; actual manufacture the least. When managers realize the advantage of equalizing these charges then will the first barrier be thrown down, and the exepense of maintenance and distribution will be reduced by larger sales; for, as surely as the day follows the night, increased consumption follows decreased rates, and profitably, too. Maintenance of high rates is further provocative of dissatisfied consumers, and also of the evils of competition.

The second essential is the sale of the vehicle for your commodity at cost, or even less. The onward march of gas as a fuel has been barred by the endeavors of gas managers to exact from consumers a profit (and generally a large one) on stoves and appliances. This is inconsistent and dangerous. If managers are willing to make an investment of from $8 to $100 for service connection and meter to obtain a consumer for illumination, one whose consumption will be problematical, especially if he is located in districts where electric lights are to be obtained, competitively or otherwise, why should he not be willing to invest an equal amount in a stove that will of a certainty yield a fixed return, keep down the peaks-of-manufacture account, and reduce the interest on fixed charges, the cost of the stove in most cases not equalling the cost of the piping to reach and hold an illuminating customer. The testimony of every gas man in the United States will confirm my belief that the average consumption of stoves in a household is far greater than the consumption for light in the same house; and that being true, no company will ever achieve success in the promotion of fuel gas until it dispels the idea that profit should be made on sales of appliances.

Fuel gas should be sold through a separate meter. The main difficulty in holding a consumer of fuel gas arises from the fact that he has no means of knowing just what he is using for fuel, because he is unable to determine whether to attribute the increase of his bill to the stove or light. He usually ends by blaming the stove and dispensing with its use. There is rarely a complaint lodged in a gas office for high bills on a gas stove consumption, and where rates are in excess of the vox populi price of $1 per 1,000 cubic feet the consumption of stoves and illuminating should be separated. The advantages to the manager in determining the value of that branch of his business by knowledge of the actual amounts used are too obvious to need any explanation.

Stoves once sold should not be left at the mercy of the consumer, but should receive the same care and attention that other appliances receive from a manager's hands. Every stove in use should be visited once in six months, inspected, adjusted, and defective or worn parts supplied free of charge. Let me ask this financial question:

If a gas manager could be guaranteed 20 per cent. return on an invested capital would not his purse strings soon be unloosed? Then to demonstrate that possibility, say that:

200 stoves cost, set up	$3,400.00
200 meters cost, set up	1,500.00
Total investment	$4,900.00
Collect from consumers for stoves, say at $10 per stove	2,000.00
Net investment	$2,900.00

(20 per cent. per annum on which is $580.)

With gas at $2 per 1,000 or less, anywhere in this district 200

* Mr. Britton prefaced his paper with these remarks: "I would like to say that the paper was written not so much for the purpose of giving my own views, but for bringing out a discussion, for much of the value of an association is not in what one may write but in what is brought out during the discussion over what was written. I hope my ideas respecting the introduction of gas stoves will be fully debated, and that when you are through with the dissection of my ideas I will have been as severely criticized as you think I deserve."

stoves will average 800 cubic feet each per month, equalling 1,920,000 cubic feet per annum, and realizing gross $3,840. It would be a very poorly managed gas company that could not realize a profit of $580 on an investment of $3,840.

Separate your gas stove room from your office. Many a sale of a gas stove has been killed by the complaint of some dissatisfied cosumer, arguing with the clerk about a lighting bill while you were trying to convince another customer of the economy of a gas stove. Besides, the proper explanation of the merits of your wares takes time and patience, and these cannot be given when other duties are engaging your time or the time of your clerks. If you cannot afford just now to have a separate store, place the stoves and appliances under liberal commissions with some firm in your city.

About three years ago I began to observe, by reference to our gas stove accounts, that month by month the number of stoves on which there was no consumption was steadily increasing, until out of about 2,200 stoves in place at that time there were about 400 showing no consumption of gas. Now I knew that the difficulty must be with the stoves, and that it was not a question of the price of gas, because we were selling stoves continually. I employed a competent person, paying her a reasonable salary, and gave her a list of these 400 people. She visited every one of them, discovered the defect, and had it remedied through the office. Inside of 18 months we had but 15 stoves showing no consumption. From these 400 stoves we gained an average of nearly 2,000 cubic feet of gas per. month, which emphasizes the necessity of paying attention to stoves after you have once sold them.

Advertise your wares. No business ever succeeded without constant notice to the public that you have the article you desire to dispose of for sale. The circulation of dodgers is worthless as an advertisement, and all the literature in the world will be ineffective against the prejudices of the people. Newspaper "ads." confronting the people every day first awaken interest, then produce inquiry, and then bring them at last to look at your stock, to listen to your reasons, to examine carefully, to buy. It will pay you to advertise, and if you have no time, or perhaps do not feel capable of writing advertisements that will attract attention, you can purchase such talent at a nominal rate from individuals or syndicates who make a specialty of writing attractive "ads." In small towns personal visits and practical demonstrations are effective means.

Sell your stoves for cash. The rental system is bad for the seller and purchaser, and the loss incident to the care of stoves returned disposes very rapidly of such profits as may seem to come from the transaction. Stoves returned for non-payment, or on account of removal, are worthless, and no self-respecting manager will ever furnish to a customer a second-hand stove, free or otherwise, and I venture the assertion that more gas sales have been permanently destroyed by this method than by any other in use.

Installment plans are a trifle better than rental, but open to the same objections, unless a sufficient amount is collected on the first payment to insure against loss.

The Golden Rules for increase of sales of gas for fuel might be written as follows:

1. As low a rate per 1,000 cubic feet as can be made consistent with your cost, eliminating desire for large profits, which will finally come in equalization of costs of manufacture, maintenance and distribution, now so divergent in most cases.

2. Separate meters and rates for fuel and illuminating gas, affording data to consumer of actual costs of each, and encouraging the manager in the promotion of that part of the business by a determination of relative sales in each and placing the burden where it properly belongs.

3. Sell stoves at cost, or less than cost, on the same principle that impels you to lay mains and set meters for additional consumers in new territory. Why not the same proportionate expense for new consumers in old territory, involving little or no addition to capital?

4. Separation of your merchandise business from your standard line, either in your own name or through others.

5. Constant care and watchfulness over stoves in use, so as to include constant use by keeping them in condition to do justice to your commodity.

6. Advertise your wares.

7. Don't offer to sell, loan, or give away second-hand apparatus. Burn them up.

The fifth rule may be emphasized by the suggestion that demonstrations of the possibilities of a stove, if given in the household by a competent person, are worth a thousand demonstration lectures in a public hall on dishes rarely employed by people who use gas stoves. The best consumers of fuel gas are the middle classes, who only want to know that a stove will economically bake bread, pies and cake, and that it will roast beef and broil steaks. They are the economists, and to them appeal all the characteristics of a gas stove: Speed, reliability, cleanliness and cheapness; and to them we must look for our greatest gain in sales. The pampered servants of well to do households are the enemies of gas stoves, and to their mistresses they are as a rule mere playthings of a moment.

Hot plates are a burden, and I fervently wish there were none in existence. They stop the sale of many a range, and are no more effective than a lava tip as an exponent of the value of gas as fuel. It would be more profitable to gas companies to give a consumer a 4-burner, 2 oven range than to allow him to purchase a 1 or 2 burner hot plate, gas companion or other device which shuts out a larger consumption through ranges.

The future profit of the gas business lies in the gas stove burner, and the progressive companies of the future will devote the same energy to the promotion of that portion of the industry that has in the past been devoted to the lighting end, and to competition with electric lighting.

The enormous quantity of stoves that are made can probably be better realized by you when I say that the Chicago Light and Fuel Company last year contracted for and had delivered to it 100,000 ranges from one manufacturer. This year they are patronizing all the manufacturers and advertising their stoves. The consumption of fuel gas is enormous. It can of course be determined upon definitely only by those companies which employ the method of separating fuel gas from other gas. Whether you make a different rate or not does not cut any figure. The salvation of the business has been the separation of the two gases. But as far as can be told, and judging from a few figures I made from Brown's Directory, the consumption of gas for stoves in the United States in the past ten years has multiplied over a thousand times. The decrease in the sales of gas would have amounted to 20 per cent. on what it then was had not fuel gas come in to help out the gas companies.

THOUGHTS ON BOILER EXPLOSIONS*.

BY T. R. PARKER.

EVOLUTION can be traced in the history of boilers since the time when steam pressures were low and boilers were of almost any shape, depending for their strength on bracing rather than thickness of shell, ⅜-inch to ½-inch being the ordinary. As pressures rose the necessary braces became too close to permit proper access to all parts of the boiler, and this led to a form of envelop that could furnish necessary strength by thickness and shape. A few standard types gained general adoption. About the time mild steel came into general use pressures had risen to the permissible limits for shells of wrought iron. The improvement in manufacture of this new boiler material permitted higher pressures to be maintained, until pressures as high as 225 pounds for boilers are to-day actually in use. The boilers of the "Campania" are 18 feet in diameter and 17 feet long. The shell plates are nearly 1⅝ inches thick, some of the individual plates being 20 feet long and 7 feet wide, carrying a working

*Abstract.

pressure of 165 pounds. She has 12 boilers of 31,000 indicated horse power and a speed of 22 knots. The "St. Louis" and "St. Paul" carry a working pressure of 210 pounds. Those of the "Minneapolis' are 20 feet long, 15 feet 9 inches diameter, and weigh 72 tons each, empty. The water in one boiler alone weighs 40 tons.

It is noted that the great weight of water in these large boilers is an element of serious danger in case of an explosion, as the quantity of energy stored in steam contained in the boiler is quite insignificant in comparison with that contained in the body of water of high temperature, yet *there is no record of a modern, well-designed high pressure boiler having exploded.* The use of higher and higher steam pressures and temperatures has been advancing rapidly of late years, and it is practically certain too that the limits of steam pressures have been reached, especially in cylindrical and large shell boilers.

The obstacles to this advance have been largely obstacles due to temperature, where metals lose their strength, since in hydraulics and compressed air work, where difficulties of temperature do not enter, pressures of 1,500 and 2,000 pounds to the square inch are practically maintained.

A great deal of thought and effort has been made in the direction of high pressure and safety devices. It was Dr. Thurston who long ago said that a cubic foot of water, heated to a temperature corresponding to 60 pounds pressure, has as much explosive energy as a pound of gunpowder; at the higher pressures now carried this would be increased fully 25 per cent. It has also been said that water could be boiled in a paper bag without burning the bag. This is simply in evidence of water as a medium of absorbing and as steam dissipating heat.

On this principle, the thin tube, small-pipe type of boiler is rapidly coming to the front, for rapidity of circulation and the development of still higher pressures which are eagerly sought for. Plans have been prepared of the small tube variety for a 23,000 indicated horse power, trans-Atlantic express steamer. The pressures carried by this type of boiler range from 250 to 400 pounds, the small diameter of the tubes encompassing the water, and the powerful circulation reducing the possibilities of large ruptures being reached, is such that they are recommending themselves and are fast being adopted by the navies of the world. Many are the forms of this type of boiler and additions are accumulating, each claiming some advance over previous efforts, but all having rapid circulation, quick generation, ease of repairs, capabilities to stand heavy pressures and possessing factors of safety.

It may be interesting to mention a few of the known types of this style of what are called pipe boilers. There are the Babcock & Wilcox, the Heine, the D'Allest, the Porcupine, the Thornycroft, the Moser, the Yarrow, the Ward, the Seabury, the Almy, the Reed, the Normand, and the Belleville. Ruptures of tubes do occur with these with the minimum of disaster.

The earliest mention of the application of steam to produce motion was the Æolipile of Hero, invented 130 B. C. But the century just drawing to a close has seen more advance in the application of steam by human thought than the record of all the preceding centuries. It is now said that it is perfectly practical to design, construct and manage steam boilers so that there is absolutely no danger of explosions. This is rather a broad statement when we consider the criminal neglect of employees, defective riveting, accumulation of sediment, grooving, corrosion and sudden and unequal expansion of metal by injudicious firing. Still it seems to be borne out by first-class, modern constructed boilers managed by intelligent supervision. But as opinions and theories, observation and practice on this subject are from many sources, we may expect to find some lines of anology that have been conceived that by investigation may afford us hints which at first sight might appear to have no foundation.

The general public believe that low water in a boiler is the one great cause of explosions. And steam (water dust, as it were) has properties that the clouds possess electrically, both negative and positive, and of greatest tension. Many attribute pitting and grooving to the effect of electrolysis, for it is said with but little doubt that atmospheric electricity, as thunder and lightning, is due in some way to *water*. At what stage of its transformation the electrification is developed by the water substance is as yet only a matter of guess work. The "meteorel" or water spout presents a phenomenon of condensed vapor forming the apex of a cone projecting from a cloud and another from the water below. The junction has been observed to be accompanied with flashes of lightning. The *causes* that produce this as well as of electricity are not as yet well known. By some authorities it is said that the electrical effects found associated with evaporation have always been accompanied by violent physical and mechanical actions which are not observed in conjunction with atmospheric electricity. That drops of rain are often individually electrified by coalescence of two or more atoms of water into one is proven by the occurrence at times of luminous rain, when the ground is feebly lit up by the multitude of tiny sparks that illuminate the ground; that flakes of falling snow also are often strongly electrified so that small sparks have been drawn from the points of umbrellas.

The reason for our complete ignorance on these points as applied to boilers seems to lie in the fact, that only can investigation be made on a scale very much larger than is attained in a laboratory. The difficulties may probably be overcome by the first nation which will go to the expense of providing the necessary means for extensive experiments. In reference to steam as water it is surmised that it may be subject to similar conditions as dust in other forms; for it is within comparatively recent times that *flour* dust could be considered one of the agents of explosive energy.

In Minneapolis, in 1878, it made a demonstration of its force by demolishing five mills, and projecting a column of flame 600 feet into the air, blowing fragments to a distance of two miles. There are also other powdered substances that will explode, such as dust of oats, meal, rice, malt and spice (these are life germs), even sawdust, candy, soap and metallic zinc; also in the compounding of drugs and chemicals in the laboratory these things assert themselves. Dust to dust, ashes to ashes seems to be an old and inevitable law. This leans us towards the theory that the various forms of energy are so intimately related in one grand system that each may in turn produce or pass into all the others.

That boilers do explode and boilers burst—by bursting is meant in opening limited in extent to the discharge of the contents of the boiler without tearing it into pieces, commonly taken to be rupture, locally, by the yielding of the weakest part to a pressure which at the moment may not be deemed excessive but which is too great for the weakened spot; if it is from poor material, faulty construction, or lack of attention to water line or opening the throttle too suddenly on high pressures, are questions that are yet open for discussion, as case after case can be cited where conditions seemed extra hazardous such as no engineer of judgment or discretion would sanction. Still men can be found who take all kinds of risk and come through unscathed, while men known to be careful, thoughtful engineers have been unfortunate enough to have these accidents occur, losing their lives or reputations, as the case may be.

Boilers are torn asunder by explosions, and the question to be solved is, "What are the conditions that cause these explosions?" for in all cases it is said like conditions produce like results. Seemingly it is by a sudden development of force, far in excess of those exhibited in regular working, where violent disruption occurs, permitting the stored heat energy of the enclosed water to be expended in enormous rapid ex-

pansion of its own mass, with such tremendous power, as if the explosion were that of a powder magazine, taking place with such extraordinary violence and destructive effect that some French writers denote them as "explosions fulminate," or fulminate explosions, the report of which is likened unto that of an enormous piece of ordnance or heavy clap of thunder, rending the boiler into many parts, broken as completely as if by a charge of dynamite. In such cases the magnitude of the shock and energy demonstrated at the instant of catastrophe produce such disastrous effect that oftentimes are terribly impressive, and by many attributed to causes yet obscure and of great potency. It is a very interesting field of inquiry, far from being a barren one, that may ultimately warrant some of the many still unexplained causes connected with violent steam boiler explosions.

If our boilers are filled to the proper level with this mother of all elementary substances, judiciously fired so that the supply equals the evaporation demanded, there would be a physical but not a chemical equilibrium; because the loss would consist of pure water or its equivalent, while the received water would contain the various mineral or saline matters of which it is the greatest solvent. It would go on increasing until chemical changes may take place either by precipitation or combination, by the deposit of suspended matter as scale, or liberation of gases which they contain, until we may have a veritable magazine of stratified elements ever active to combine in definite proportions when conditions favor, for there is not one grain of sand nor one invisible corpuscle of floating matter that does not come under the same law that governs the most mighty planet and all forms of matter that are aggregated under that law. They are so vast and complex that they may only be realized in the sweep of ages. When we think of the quantity and possible quality of vital force contained in the myriads of infinitesimal life that are injected at each throb of the boiler pump, with properties vieing with the electric eel, the torpedo or the unfathomed possibilities of the glow worm, energy may be freed as they perish, chemical actions may arise that are too complex and numerous, caused by these hydrothermal conditions, that will lead us into a train of hypothesis entirely metaphysical, that is apt to carry us into a chaos of unbridled phantasy, until the tired brain returns to itself with the suggestion that speculation may be the soul of thought, but facts are the body thereof. For the Chief Engineer of the universe who knows all powers and properities, has worked wonders without end with this medium, water, for us to ponder over and marvel at; but time forbids in the limits of this article to speak of the affinity of electricity for humidity, or for water as a body, or the fatigue of steel, or its magnetic character, or the part that copper or brass furnishings plays in the decomposition in boilers of iron and steel, of the destructive combination of oxygen with boiler sheets, disturbing the proportions of water. Of zinc, in its performance placed in the interior of boilers for the preservation of the same to its own deterioration. Of the electric properties of fire. Of the limits in size of boilers for the work to be performed, of the dangerous possibilities of priming, of the theory of sphericity over the dazzling heat of the furnace. The realm is vast and various, requiring volumes instead of a paper like this. We will terminate by referring to the efforts of the metallurgical engineer whose mark of genius in conjunction with the mechanical engineer is evident at every point, with results undreamed of a decade ago.

The steel maker has supplied the constructor with a material of a quality and thickness that brings disaster seemingly to a minimum; but it is still a matter of strength against power, because boilers do explode when unable to contain the spasms of pressure within. So, putting the thing into plain English, are we not working with bottled up thunder and lightning, or in other words, oxygen and hydrogen. Or is it that water is the reservoir of all energy? As to the best known means of avoiding these conditions we are presented with the reports and performances, as well as the general adoption as far as possible, of the gas engine of to-day, whose performance the steam engine and boiler cannot hope to equal, and the possibilities of still greater efficiency have forced attention to its claims, in the steam engine's own domain. For a little less than 11 pounds of steam and a little more than one pound of coal to the horse power are apparently the ultimate limits of steam engine economy. On the other hand gas engines using "producer gas" regularly yield one horse power to about ⅞ of a pound of coal; in both cases the terms are in indicated horse power.

The mechanical efficiency of the gas engine is now about the same as that of the compound, triple expansion steam engine. These things being so by its adoption boiler explosions will become in a measure things of the past.

THE INVESTIGATION OF GAS PROCESSES.

BY A. C. HUMPHREY, M. E., M. I. C. E.

HAVING recently been called to the Pacific Coast to make an investigation of the Hall gas process, and having in the course of my work met with the usual difficulties and dangers, it occurred to me that a subject was here suggested which afforded me the oportunity of complying with the repeated requests from your officers for a paper.

Apparently a few words of warning may not be without value, for it does not seem to be generally understood, even amongst gas engineers, that the investigation of a new process is a thing to be taken up cautiously and with a due sense of personal responsibility.

For 25 years I have been called upon to investigate the claims of gas processes, and in a majority of cases a detailed examination was not required to convince me that the claims made by the promoters were impossible of fulfillment. This suggests the first danger; namely, that we may become so accustomed to not finding merit that we may be influenced to reject meritorious cases without adequate investigation. Here we must learn that while we can, and should, avail ourselves of our experiences to better safeguard us against ignorance and fraud, we should be careful to bring to each case a mind open to conviction.

In many cases within my experience the claims were manifestly so impossible of fulfillment that not only was an investigation unnecessary for my own information but it was also unnecessary for the guidance of my clients. In these cases, however, it has not infrequently been found necessary to make an exhaustive and expensive investigation to be in a position to better satisfy the investing public and the municipal authorities, who generally are not competent to form a correct judgment except through a simple comparison of working results.

Unfortunately it is not sufficient that we who are chiefly interested should know the facts, but we must be prepared to convince both those who are incapable of understanding, and those who are unwilling to accept, arguments and demonstrations based upon the established laws of science. The instance referred to in my opening was a case in point.

The claims made for this process were known by my clients and me to be incapable of verification; but others had to be convinced, and, as the claims were based upon commercial results said to have been obtained in San Francisco, it became necessary to make a critical examination on the ground.

In one notable case, about fifteen years ago, I was called upon to investigate a process which was making a stir in the gas world, and as usual one or two gas engineers had been induced to lend the process some support. One of the claims made for the process was sufficient to condemn it, but as the promoters were able to show letters of endorsement from two

prominent professors, as an influential stockholder in my company had been convinced of the validity of the claims, and the contemplation of the fabulous wealth to be realized from his small investment, if the claims were verified, had temporarily impaired his judgment, it was found necessary to make a complete test in order that the truth might be more readily demonstrated.

The claim referred to was that from a barrel of crude oil 250,000 to 500,000 feet of gas could be produced, equal in quality or superior to the city gas as ordinarily supplied, and that after extracting this volume of gas from the oil there would remain "nearly a full barrel of oil," which, by the treatment, would be so improved in quality as a lubricant that it could be sold for more than the full barrel originally cost.

It is sometimes well to reduce such absurdities to actual figures. Assume 300 pounds as the weight of the full barrel of oil and 21,000 British thermal units per pound of oil. Take the quantity of gas produced as that of the lower limit, and assume 650 British thermal units per cubic foot as being a fair average for city gas:

300 pounds of oil at 21,000 gives....	6,300,000 B.T.U.
250,000 cubic feet gas at 650 gives..	162,500,000 B.T.U.
Deficit	156,200,000 B.T.U.

So, assuming that all the oil were converted into gas, reserving none of it for sale as a lubricant, according to the claim, there was a gas product obtained which contained 156,000,000 more heat units than were originally contained in the barrel of oil from which the gas was produced.

The right to operate this process for certain States was valued by the promoters at $25,000,000. The exclusive rights to such a perpetual motion scheme were cheap at the price.

The fact that favorable opinions were obtained by the promoters from two well-known and reputable professors points to a danger of a very grave character. Here were two scientists, professors in one of the best of the engineering institutions, *apparently* vouching for the truth of the claims made. Were their statements as made correct? Probably they were, but neither statement was complete.

One certificate simply stated that a certain volume of gas was made from a certain quantity of oil, and the other certificate stated that the gas examined had certain photometric and calorific values.

When read together, as intended, it was natural that the assumption should be made that both statements referred to the same test; such was not the fact. One investigator saw a certain quantity of material consumed, and saw as a result a certain volume of gas pass through the meter and gave a certificate to that effect. The other investigator, *on another occasion*, saw gas being produced, and the quality was tested without regard to the quantity of oil used or volume of gas produced and gave a certificate accordingly.

As the process was one of the "greased air" class, it is easily seen that in the volume test there was no difficulty in getting the result desired, provided there was no coincident examination for quality. The volume of gas produced was only limited by the volume of air blown through the apparatus. When the test for quality was made the air was restricted and oil was used without stint.

It is a lamentable fact that some of our professional men can be misled into making these partial statements, and some of them are greatly grieved if in consequence their integrity is later called in question. The statement should go unchallenged that such incomplete, unguarded certificates are either the result of a willingness to deceive, of culpable carelessness or of lack of common sense. Certain it is that such certificates should be discredited.

The only way I know of to avoid danger in this connection is by refusing to accept the endorsements of any except those who we personally know to be qualified by training, experience and character to give a reliable opinion on the particular question involved.

In making our test of this "greased air" process my force was constantly at work for six weeks trying to measure the gas produced from a given quantity of oil and to determine the *average* photometric and calorific values of this gas. The vessels which received the oil, and through which the air was blown, were boiler shells with heads and bottoms riveted on the only openings being the connections for oil and air. It was, therefore, difficult to determine whether the oil admitted to the carburetting vessels had been all absorbed and also to prevent the surreptitious admission of oil when our men were off guard. The regular oil admission pipes were located and brought under our control, but we still had reason to doubt the accuracy of some of our results. Our watchfulness was finally rewarded by the discovery of a small pipe attached to one of the carburetting chambers, and this pipe was evidently used for the unauthorized supply of oil to the apparatus. The valve on this pipe was closed and sealed to prevent all tampering and preparations were completed for making the final test the next day. That night the experimental works mysteriously took fire and the apparatus was so disabled that the test could not be completed. But we had done enough to disprove the claims made, and my assistants in charge obtained an experience which served thereafter to effectually put them on their guard against doctored results, and we all had learned to regard with suspicion partial certificates covering isolated steps of a process.

Often when we are called upon to consider claims for results greatly superior to those we are obtaining by the established processes, we are able to at once dispose of them by calling for exact information as to how the comparisons were made, how the material used and the gas produced were measured, how the photometric and calorific values of the gas were determined, and the like.

A favorite form of statement employed by promoters and patent enthusiasts is that their process will cut the cost of gas in half. In such cases it is well to require the promoter to show upon what basis of established practice he expects to show his saving of fifty per cent. As a rule it will be found that he is making his comparisons with practice which is or should be obsolete, and that he is ignorant of what constitutes present good practice.

It will almost invariably be found upon cross examination that the extravagant claims made for a new process are not even based upon any complete test. Almost without exception when I have started to test these experimental installations, I have found that no provisions had as yet been made for a complete determination of manufacturing results. One or more of the pieces of apparatus required for measuring the material used and the gas produced have been wanting, and it was at once apparent that the claims made, said to be based upon results actually obtained, were simply based upon crude estimates and the inventor's hopes.

It has been a most common experience to find no station meter in use, and it has been quite rare to find a bar photometer, a calorimeter or apparatus for chemical analysis. And further, where such apparatus has been found it has generally been determined upon test to be defective and unreliable. Sometimes these deficiencies have been the result of incompetence, inexperience or carelessness, and sometimes they have been the result of fraudulent intent.

One notable instance I have in mind where the inventor, a man of reputation, had been led astray by his lack of knowledge of photometry. He claimed that his method of treating gas after it left the retort resulted in an increase in photometric value of about two candles. After some years, this gentleman's works fell under my control and I discovered that his photometer was faulty in the extreme, and that it was im-

possible by its use to make any exact candle power comparisons.

For many years one of our well-known makers sent out photometers equipped with candle balances which were beautiful to look at and expensive to purchase, but which were absolutely valueless for the purpose for which they were intended; in fact more reliable results were obtainable by discarding the balance and assuming the candle consumption to be normal.

Especial caution should be exercised in accepting statements which depend upon accurate photometric determinations. There are many men who do routine photometric work with practical accuracy who are not necessarily qualified to make photometric determinations involving conditions to which they have not been accustomed. As long as the regular course is pursued, and the object is simply to determine if the day's gas product is up to standard there is no difficulty; but even a wide variation in candle power of the gas examined might be sufficient to completely destroy the accuracy of the test. This point has been repeatedly forced upon my attention, and two striking cases have been before me while this paper has been in preparation.

In some cases it was not difficult to convince the operators of the errors or their cause, but in many other cases the faulty methods were persisted in, showing that the operators were uninstructed as to the principles of photometry, and incapable of supplying accurate data where it is a question of applying principles instead of taking certain prescribed steps. Again, certain photometers which have been proved to be reliable for certain routine work probably will be found quite inadequate for accurate comparisons where varying conditions are encountered. It is well to further bear in mind that not many of the questions which come up as to the value of a new process can be determined without involving these very points as to candle power value, and, therefore, the accuracy of the photometer and the ability of the operator are prime considerations.

As a rule where I have made complete examinations of processes, I have been finally convinced that, in spite of most definite and extraordinary claims as to results actually obtained, no previous complete examination had been made.

In the case of a process at one time very prominent, we were called upon to verify or disprove claims which were revolutionary. Some of the persons interested were most respectable and responsible. They thoroughly believed in the process under their control. We took charge of the works for about six weeks. It took us some three weeks to get ready for an accurate test, as there was no station meter, no bar photometer, no reliable means for weighing the coal and for measuring the oil.

The final result was to demonstrate that the gas was costing at least double the cost as claimed by the promotors. The figures in the past had been obtained by measuring the gas in the holder without correction for the temperature, which was excessive. The fact that the ruinously high apparent leakage, due to this overestimate of the make, had not attracted especial attention from the owners went simply to show how blindly investors accept statements which promise them large profits. The candle power of the gas had not been measured but had been arrived at by a liberal system of guessing. Upon taking inventory of the oil and coal, both were found to be short, the coal to an amount almost equal to the amount charged to gas making. In other words, the coal consumed had been almost double the amount included in the promoter's statement of cost.

This same process was afterward heard from at intervals in gas associations meetings, and was vouched for by a man who apparently wished to be fair and whose statement carried some weight. Some years later I had the opportunity to analyze the records at this gentleman's works also, and I found that there was no station meter in use, that the gas was made only in emergencies and sent out as part of a mixture, and there were no means of correctly estimating what percentage of the mixture should be fairly credited to this process. This gentleman and his friends later defended his course by saying that he stated the results as he believed them to be, and that he did not pretend to be a gas engineer.

I claim that this man, as the responsible head of a gas company, could not avoid his responsibility for misleading enquirers as to the value of this process by acknowledging under cross examination that he had simply stated the facts as he believed them to be, and that he did not pretend to be capable of giving an expert opinion. In spite of this later disclaimer his favorable opinion of the process had already been quite generally accepted and used as coming from a man believed to be both capable and honest.

The failure of agreement between facts and claims is sometimes due to the ignorance of the promoters, sometimes to their irresponsible enthusiasm, and often to a direct intention to deceive.

The continuous process has been a favorable subject for the inventor and promoter.

We are generally met with the statement that the process under consideration is peculiar in method and result, and the nitrogen supposed to be necessarily present in the product of a continuous cupola process is not present in this case, or if present is so changed in character as to be a distinct benefit instead of a drawback. The action of electricity is not infrequently claimed as giving this much to be desired result. The electricity is supposed to take hold of the inert, non-combustible nitrogen, and transform it into a combustible gas. Those who dispute the claim are at once pilloried as "old fashioned," "so-called experts," "professors," "narrow minded opponents of progress," etc., etc. Whenever a scientific fact can be brought forward seemingly to support some portion of the promoters' claims, it is done with easy confidence, but, perhaps in the next breath, with impudent inconsistency, science and scientists are condemned because they have been found to be in conflict with some other portion of the claims.

In the Hall process previously referred to we find great prominence is given to the claim for electrical action. This process was revived and brought to San Francisco and claims were made in its behalf that were known by well informed gas engineers to be beyond acceptance. It was a continuous cupola process, the gas being made while the air for renewal of heats was being passed through the apparatus. The stoking and coaling arrangements were supposed to be automatic, and the nitrogen in the product, as a necessary result of the coincident blowing and gas making, was supposed to be converted into a combustible gas by electric, chemico electric or catalytic action. To support this view we were also reminded that certain well-known scientists had recently discovered that the gas that we had supposed to be nitrogen, an element, was now found to be a compound of many other elements. Thus a doubt was raised in the minds of some as to the identity of that incombustible residue from chemical analysis, which is generally recorded as nitrogen even though it may contain minute qualities of other inert gases.

The skillful promoter of this process made much of this point, and it was difficult to meet him before a gallery audience, in spite of the fact that it could be shown that the discoverers of argon, cypton, metargon, neon, and xenon only claimed that the total of these gases was about 1 per cent of the atmosphere or 1¼ per cent. of the nitrogen, and also that these gases, like nitrogen, were inert and, therefore, it was immaterial whether the residue from analysis was called nitrogen, argon or what not.

Here certain scientists were quoted that they might be used as allies. But when such well-known scientists as President

Morton, of Stevens Institute, Professor Barker, of the University of Pennsylvania, and others testified that the apparatus as built and operated could not produce the electrical action claimed, these gentlemen and scientists in general were held up to derision.

Usually the promoter is well equipped in one particular. He is a man of nimble wit and ready tongue, and often in a duel of words before a gallery audience he is more than a match for his opponent, who thought perhaps competent and honest is not necessarily trained in controversial debate.

Even when a formal hearing is had before some legislative body, the adroit promoter's superficial presentation of his subject is often more convincing than the dry facts presented by the other side. To attack a gas company is generally popular, and this assists him to create the desired impression. Where ignorance and perhaps dishonesty on the part of the advocate of a process is backed up by the ignorance or dishonesty on the part of the municipal authorities, as unfortunately is too often the case, then indeed is it important that no pains should be spared that the truth may be plainly set forth, no matter how self-evident to us that truth may appear to be.

Often the claims of the promoter can be completely disproved from the printed documents submitted in proof of the claims. As an example, the Harris process was boomed at one time by the use of a pamphlet, from which the two following statements could be taken by reference to different pages.

1st. One ton of coal would produce 200,000 cubic feet of gas; 2d, the heating power of this gas would be equal to 80 per cent. of the heating power of natural gas.

These two claims taken together are sufficient to condemn the Harris or any other process, for the heating value of the product cannot exceed the heating value of the coal from which it is produced. Otherwise we should get something from nothing and perpetual motion would be within our grasp.

Good bituminous coal gives say 14,500 British thermal units per pound, and natural gas gives, say, 1,000 British thermal units per cubic foot; 2,000 pounds of coal, then, gives 29,000,000 British thermal units, but the gas produced from this coal, according to the claims, gives:

$$200{,}000 \times 1{,}000 \times .08 = 160{,}000{,}000 \text{ B. T. U.}$$

or 131,000,000 British thermal units more than the coal from which it was produced.

In spite of this most apparent weakness this Harris process was backed by many well-known bankers, politicians, doctors, lawyers and statesmen, and its promoters were successful in interesting many who could ill afford a bad investment.

The Hall process had a similar, though more extended, record. Though repeatedly proved a failure in practice, new fields were invaded, new investors were enthused and the battle between truth and error had to be again and again fought. Here in San Francisco, and the neighboring city of Oakland, the process was introduced and, in spite of the many failures which had been registered against it in the East, capital was again found for its support.

Certain progress was made in San Francisco against the established companies, largely because the promoters were fortunate in being able to avail themselves of the increased efficiency of the incandescent burner as compared with the open tip burner, the former not having been introduced to any considerable extent by the older companies. With the ordinary observer, the Hall process, not the incandescent burner, obtained the credit for this economy.*

Thus there was a certain appearance of success, though as a fact not one of the extraordinary claims made for the Hall process could be verified from the San Francisco results. The quantities of materials used were far in excess of the claims, the quality of the gas was inferior, and the electrical action claimed for the "flower-pot" filling of the converters was non-existent.

This appearance of success in San Francisco was used to revivify the process in the East, and so successful was the promoter in impressing his points upon certain important men, that it was only after a long and determined fight that the truth was again made evident and the attempt to introduce the process into two or three cities on the Atlantic seaboard was defeated. Finally, as the result of hard, commercial experience the process was abandoned both here and in Oakland.

As part of my investigation, a gas similar to the Hall gas was produced by the continuous running of a regular, double superheater water gas apparatus, the fixing chambers being filled with firebrick in accordance with regular practice, thus disproving the claim of special virtue for the electrical flower-pot filling as used in the Hall process.

Possibly we may be again troubled with the continuous process man, who will claim that his process transmutes the nitrogen resulting from the air blast into a combustible gas. In such a case, remember that with a little practice you can with your regular water gas apparatus at least duplicate his actual results and thus prove that if his results are to be desired you have them at your command without his assistance.

It is a remarkable fact that it is by processes of this character, wherein the element of the marvelous is included, that the uninstructed public can be the most easily deceived. The promoter suggests that a very small investment will bring in great returns, and, therefore, a small "flyer" is a fair speculation; that the gas experts are naturally opposed to him because his success means their loss; that every previous great advance in industrial science has been opposed by the experts of the day, and the steam engine, the telegraph, the telephone and gas itself are instanced.

The promoter's cause is almost always helped along by the illadvised endorsement or partial endorsement of school men who have the name of being fair and scientific, but who in reality are not qualified to make a complete examination or to give a conclusive opinion. The partial certificate, already alluded to, is a most dangerous element in the situation.

Again, the promoter can usually obtain the more or less complete endorsement of some man well known in the gas world and believed by many to be a practical, able and honest gas engineer. Sometimes this endorsement is obtained by the payment of a "professional" fee, and sometimes it is the enthusiasm and lack of self-control of the engineer which hurries him into a position from which later he would gladly recede. We can all call to mind instances under this last head.

I have such an instance in mind, where an engineer well known and to some favorably known, reported in favor of a certain much advertised process, and in doing so made it the occasion for pointing out that his analysis of the gases distributed in a number of our cities demonstrated that the gas engineers generally had been deceiving themselves as to the true composition of these gases. This report was by some taken seriously and produced alarm. It finally developed that the methods of chemical analysis from which these revolutionary results were obtained were absolutely incorrect and valueless. This points the lesson that while we should investigate with an open mind, if we obtain results which completely contradict the results for years obtained by the great body of our fellow workers, we should incline to the belief that this failure to agree is the result of some error of our own.

There is another point which calls for special comment. Frequently when a new process is first bulletined, not only the public is deceived but also a considerable part of the gas fraternity, and this perhaps because the process seems to be making favor with the public and with the State and municipal governments. Battles are fought over the process, hear-

*The so-called electrical features of the Hall process are described in detail in their expose made in THE JOURNAL for February, 1898—Vol. V, page 93.—THE EDITOR.

ing are had before councils, papers are read before gas associations, discussions are carried on in the gas journals, and, finally, if the process is unable to maintain itself in practical competition, the collapse comes. Then the whole matter is apparently forgotten and peace again reigns. But the promoter again appears in the field with the same process *or its equivalent*, and now we find the public again deceived and gas men again in doubt and alarmed. We seem to get but little protection from our experiences. In my opinion this is because there is too little real investigation, and we are, therefore, quickly moved by gossip and current opinion. We do not, as we should, get down to the consideration of principles. On the other hand, even a process without merit should not be despised by the established companies, for not infrequently such a process, for which radical claims are made as to novelty and economy, secures a footing not obtainable by a process for which less is claimed but from which more can be obtained.

Under the commercial test of competition the faulty process must be amended or actually discarded, but in the meantime a position more or less secure has perhaps been established by the new comer.

The best security against such attacks, although unfortunately this is not always sufficient, is to share with our customers the economies to be derived from an intelligent, efficient, up-to-date management. Let me suggest to the younger members of the profession that when a process question is before them for solution certain simple steps may well be followed:

1. Obtain a *definite* statement of claims, covering results, apparatus and methods.

2. If it is claimed that from a given amount of gas making material a gas product can be obtained which will develop a greater number of heat units than the material itself contains, reject the claims.

3. From a preliminary examination of the claims and the surrounding conditions, decide whether or no an investigation is advisable.

4. If you decide in the affirmative, prepare to do your work guardedly, but with an open mind.

5. Accept no statements unless vouched for by some one known to you to be thoroughly competent and trustworthy. If possible, even then check up for yourself.

6. Before finally deciding to accept or endorse the process, make a working test, being careful to see that all conditions are such as can be obtained in practice. Measure all material used and measure and value the product.

Be sure all apparatus used for such measurements is carefully standardized, and take nothing for granted as to the course of the gas, the connections to the photometer, and the like. In other words, be sure that the gas you measure and value is the gas produced from the materials you have measured.

7. If commercial figures are quoted in support of the claims do not accept them without a critical expert examination of the books. Remember that it is not difficult to so keep books of account as to hide the truth.

8. Remember that an investigation and report afford quite as much opportunity for the exercise of common sense as of technical skill. If there are any modifying or qualifying conditions especially to be borne in mind in considering your report, draw specific attention to them either in your summary or your letter of enclosure.

9. Remember, if you make a report, you are responsible for its findings. Express no definite opinion unless you are fully satisfied with the thoroughness of your investigation. An incorrect opinion either for or against the process must work an injury.

10. Let no consideration of personal gain influence your judgment. Remember, there are refined and insidious methods of presenting such corrupting arguments.

CRUDE PETROLEUM IN BENCH FIRING*.

BY DR. R. M. POWERS.

ABOUT three years ago Mr. R. L. Clarke, who was then the engineer of our electric light plant, and is now superintendent of the San Diego Gas and Electric Light Company, placed an oil burner under one of the benches, and as a result of the experiment I am satisfied that we have saved money by the use of oil. Herewith is submitted a test continued for three months with coke, tar and crude oil on two benches of 6's, Weber half-depth regenerative furnaces. The output and conditions were practically the same for the three months. During one month we used 134,220 lbs. of Wallsend coke, and in the next month we used 7,680 gallons of tar, and the third month we used 8,745 gallons of oil. The oil cost us $1.47 per barrel, or 3½ cents per gallon, in our storage tank. 8,745 gallons equaled 7,680 gallons of tar, equaled 134,220 lbs., or 67.11 tons, of coke.

8,745 gallons oil equal or cost $306.075 equals 3½ cents per gallon.

7,680 gallons tar worth for fuel $306.075 equals 3.99 cents per gallon.

67.11 tons of coke has a fuel value of $4.56 per ton.

For steam purposes we have obtained practically the same results, the relative value of our fuel under our boilers being, oil 3½ cents; tar, 4.2 cents; coke, $4.66 per ton; and Nanaimo coal, $5.88 per ton. Last season we operated our water gas plant and commenced by using what was billed to us as "Washed Sopris" coke, costing us $11.35 per ton. We next used Cerrillos anthracite, costing in our yard $10.85 per ton. We got better results from the antracite, but owing to delay in receiving shipments we were compelled to use our gas coke with the following results: Taking Cerrillos anthracite at $10.85 per ton as a basis, the Sopris coke had a relative value of only $8.72 per ton, while our Wallsend and Greta coke was relatively worth $9.04 per ton. It is evident from the foregoing that we cannot afford to burn coke under our benches with a fuel value of $4.56 per ton, while in our generator it has a relative value of $9.04; neither can we afford to pay $8.55, which is the present price of Nanaimo coal, for steam purposes, while it has a relative value of only $5.88 as compared with oil at 3½ cents per gallon, and tar at 4.2 cents. The inference, therefore, is that the company making coal gas can afford to use oil at $1.50 per barrel, and sell its coke to the company making water gas exclusively, and the water gas company can afford to pay a net price of $9 per ton for gas house coke in comparison with other fuel. These figures will of course vary with existing conditions, but will serve as a basis for calculation. In many sections of the State the specific gravity of crude oil ranges from 11 to 16 deg., and the heavy oil can doubtless be purchased at a less figure than oil of 16 gravity and upwards. Our method of using crude oil is described by our superintendent, Mr. Clarke, as follows: "The burner is placed near the grates and throws a fan-shaped flame up through the furnace, equally heating all the bridges, and not so intense on a few of the back ones as in the former arrangement. The fan-shaped flame in the furnace creates a proper circulation of the hot gases around the retorts, being up in the center and down on the sides to the flues. This serves to keep an even heat in the retorts up to the necks and incidentally serves to make the stoker 'hot in the collar.'" The burner in use in our works was devised by Mr. Clarke, and a sketch with description has been sent to Mr. Hollidge of the Wrinkle Department.

Aside from the actual saving to be derived from the use of crude oil for firing benches, the additional arguments which every salesman and superintendent employ when urging the use of gas for fuel are: It is always under control; it is clean, comparatively economical and in every way satisfactory, with no clinker or dirt or ashes to accumulate; but more than all, it meets that most desired of all requirements of the gas manager —economy.

*Abstract.